EXTRACTS

FROM THE ANNUAL REPORT OF THE

MEDICAL OFFICER

OF

THE LOCAL GOVERNMENT BOARD

For 1884.

DISINFECTION BY HEAT.

BEING A REPORT BY

H. F. PARSONS, M.D.

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Dr. Parsons's Report on Disinfection by Heat.

Dr. Parsons, in a lengthened experimental study of disinfection by heat, has had a care to take destruction of the most stable known infective matter as the test of true "disinfection." Examining, in conjunction with Dr. Klein, the suitability for the purpose of this study, of the virus of swine plague and of tuberculosis and of anthrax—all of which admit of being, before and after experimental heating, put to the test upon animals—the observers soon came to the conclusion that, of these infections, anthrax material was the most resistant to every form of heat; and they were able to proceed on the assumption that such arrangements as would afford a heat adequate to destroy anthrax, not only in its bacillar but in its spore form, might be trusted to destroy the potency of infectious matter generally. Heat disinfection

Having determined by a prolonged series of experiments the degree of heat to be attained, and the combinations with moisture in which the heat was best operative, Dr. Parsons examined the physical conditions for its production in the required combinations; and then continued his research into practical questions concerning the mechanism by which the needful conditions for heat disinfection could be so obtained. It was seen to be necessary so to arrange an apparatus that heat should penetrate bulky and non-conducting articles, and so that the heat could be used to dainty fabrics without injury to their appearance or to their texture. Dr. Parsons came to the conclusion that all infected articles which could be treated by boiling water, so as to penetrate the substance efficiently by this means without injury to the articles themselves, could not be so well disinfected in any other way as by simple boiling for a few minutes; that infected articles which from their nature did not lend themselves to such boiling had best be treated with high-

pressure steam, with such arrangement as would ensure complete penetration of the steam at its high temperature, and that such treatment might be relied on to destroy any infective quality in them with the thoroughness and rapidity that were desired; and that in the comparatively few cases where the articles to be disinfected would be injured by steam, a dry heat of 240° F. would, if sufficiently prolonged, bring about the desired destruction of infection, but that this could not, in the case of most articles, be had by means of dry heat without an inconvenient length of exposure.

In the end, having become familiar with the requisite qualities of a good disinfection chamber, Dr. Parsons is able to report, as the result of experiment on a variety of existing forms, that he finds some exceedingly well adapted to the purposes of sanitary authorities; and he considers these in detail in the text of his report. So far as we are at present informed, there is no sort of disinfector or disinfectant that can rank by the side of heat; and of all methods of applying heat, the use of high-pressure steam is by far the most generally available.

GEORGE BUCHANAN.

March, 1885.

REPORT.

Report on Disinfection by Heat; by Dr. Parsons.

On Disinfection by Heat; by Dr. Parsons.

Division of subject.

In considering the applicability of heat as a means of disinfection, several distinct questions present themselves for solution. Thus we have first of all to determine what degree of heat and duration of exposure are necessary under different conditions, as of moisture and dryness, in order to destroy with certainty the activity of the contagia of infectious disease.

We have next to ascertain how the required degree of heat may be made to penetrate through bulky and badly conducting articles, *e.g.*, of clothing and bedding, for the disinfection of which the application of heat is especially employed.

We have also to learn whether such articles can be submitted to the required degree of heat without injury, for if not, disinfection presents little advantage over destruction.

I.—*The Degree of Heat heretofore held to be necessary for the Destruction of the Contagia of Infectious Diseases.*

History.

Dr. Henry's experiments.

The earliest experiments on disinfection by heat, as distinguished, on the one hand, from destruction by fire, and on the other, from mere washing in boiling water, appear to be those made by Dr. Henry, F.R.S., of Manchester, and published in the Philosophical Magazine for 1831.

These experiments were made with a copper vessel surrounded with a steam jacket; the steam, which was used at atmospheric pressure, *i.e.*, at a temperature not exceeding 212° F., being admitted only into the casing, so that it did not come into contact with the objects to be disinfected.

On vaccine.

Experiments were first made with vaccine lymph dried on glass at ordinary temperatures. It was found that exposures of four hours' duration to 180° F., four hours to 140° F., two to three hours to 160°–165° F., two hours to 192° F., and two hours to 150° F., destroyed the activity of vaccine lymph. The original activity of the lymph was proved by the subsequent successful vaccination of the same children with unheated portions of the same lymph. On the other hand, exposure to a heat of 120° F. for three hours did not impair the activity of vaccine lymph.

On typhus.

Three flannel waistcoats were worn successively each for several hours by a person suffering from contagious typhus. No. 1, after one and three-quarter hour's exposure to a heat of 205° F., was kept for two hours close under the nostrils of a person engaged in writing, who was fatigued and had fasted for eight hours. No. 2, after similar heating, was worn for two hours next the body of the same person. No. 3, after similar exposure to heat, was kept for 26 days in an air-tight canister, and was then placed for four hours close to the face of the same person. No injurious effects followed. It was not, however, shown that the person in question was susceptible of the disease.

And on scarlet fever.

Similar experiments were made with flannel waistcoats taken from the bodies of scarlet fever patients, and after exposure to heat, worn by children who were known not to have previously suffered from the disease. None of these children contracted scarlet fever, although kept under careful observation in order that no slight symptom might pass unobserved. The exposures in these experiments were as follows: four and half hours to 204° F., two and half hours to from 200° to 204° F., three hours to 204° F., two hours to 200° F., and one hour to 204° F.

Here again, however, the proof was for obvious reasons not completed by causing the children to contract the disease by wearing garments equally infected but unheated.

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So far as these experiments go, they tend to show that the contagia of the ordinary infectious diseases are destroyed by dry heat at temperatures below the boiling point of water.

Dr. Baxter's experiments on vaccine.

A series of experiments on the degree of heat necessary to destroy the activity of vaccine lymph was made by Dr. Baxter (Report of Medical Officer of Privy Council and Local Government Board, New Series, No. VI., 1875, pp. 228–9). The experiments were made with dried lymph on ivory points; these were attached to the bulb of a thermometer which was enclosed in a test tube in such a manner as not to touch the side of the tube; the test tube was then heated by being immersed in a water bath. The duration of exposure was half an hour in all cases. Ten experiments were made: in each the heated points being used to inoculate three places on one arm of a child, while three other points charged with lymph from the same source were used to inoculate corresponding places on the other arm. One of the children so inoculated did not return for inspection; in the other cases it was found that exposure for half an hour to a temperature rising in that time from 167° to 176° F., or to temperatures below this, did not impair the activity of the lymph, while exposure for the same length of time to a temperature rising from 185° to 194° F., or above, destroyed its activity. The difference between these results and Dr. Henry's is explained by Dr. Baxter as attributable to the difference in the duration of the exposure, which in Dr. Henry's experiments was from two to four hours, in his own only half an hour; degree of heat and length of exposure being mutually compensatory.

Carsten and Coert on animal vaccine.

In Holland Drs. Carsten and Coert have made a large number of experiments on the temperature necessary to destroy the activity of calf lymph. They find that lymph heated to the boiling point of water is invariably sterilised. They arrive at the following conclusions:—

1. Animal vaccine heated to 148° F. for 30 minutes loses its potency.
2. Animal vaccine heated to 125°·6 for 30 minutes does not lose its potency.
3. The highest heat which vaccine can support without losing its potency is probably between 125°·6 and 129°·2 F.

The experiments of Dr. Henry upon the degree of heat necessary to destroy the contagia of human communicable diseases other than vaccinia do not appear to have been repeated by subsequent investigators, doubtless owing to the ethical objections to the performance of such experiments on the human subject. Observations, however, have from time to time been recorded tending to show that the contagia of the commoner infectious disorders, and of yellow fever* and puerperal fever† do not survive exposure to a temperature of 212° F.

Davaine on anthrax

Davaine (Comptes Rendus, Sept. 29th, 1873) ascertained that the blood of an animal suffering from anthrax, even when enormously diluted with water, when inoculated into a guinea-pig, caused its speedy death. Such dilutions (of $\frac{1}{10000}$) were exposed to heat, and subsequently inoculated, when it was found that their virulence was destroyed by exposures of 5 minutes to 131° F., 10 minutes to 122°, or 15 minutes to 118·4°. When the blood was not diluted it required for

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* E. Harris. The Utility and Application of Heat as a Disinfectant. Boston, U.S.A., 1860.

† Von Busch. Neue Zeitschrift für Geburtskunde. 1852, p. 313.

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and septicæmia.

complete disinfection an exposure of 15 minutes to 123°·8. On the other hand, the blood, when previously dried over chloride of calcium, retained its virulence after an exposure to 212° F. for five minutes.

Davaine states that the virus of septicæmia is not destroyed by a prolonged ebullition.

In the experiments, however, of Dreyer (Archiv. für experimentelle Pathologie, 1874, p. 182), rabbits inoculated with septicæmic blood which had been previously mixed with a few drops of water and boiled (it is not stated for how long), remained well.

Bacterial theory of infectious diseases.

The modern discovery that certain communicable diseases, *e.g.*, anthrax, are connected with the presence of microbes in the blood and tissues,—a proposition, which from analogy, it is thought may ultimately be found applicable to all diseases of the same class,—has led to the inference that by ascertaining under what circumstances micro-organisms, or the more resistant among them, are destroyed, the conditions necessary for effectual disinfection may be learnt.

Experiments of Koch and coadjutors.

On various organisms.

Upon this basis an extensive and important series of researches has been conducted by Koch and his coadjutors (Mittheilungen aus dem kaiserlichen Gesundheitsamte. Berlin, 1881). The organisms employed in these researches as subjects of experiment comprised, as examples of organisms devoid of spores, the micrococcus prodigiosus, and the bacterium of blue pus and of septicæmia, and, as examples of spore-bearing kinds, the bacilli of anthrax, and those found in hay and in garden earth. The samples having been exposed to processes of disinfection, the subsequent capacity for development of the organisms so treated was tested by cultivation on slices of potato, or on gelatine containing blood serum, and in some instances by inoculation of animals. Control experiments were made at the same time with portions of the material not so exposed.

With chemical agents.

The general result of the experiments with chemical agents was to show the comparative or entire inertness as germicides of most of the substances commonly received as disinfectants, as carbolic and sulphurous acids, chloride of zinc, &c. The spores of the bacillus anthracis were, however, destroyed by exposure for one day to the action in watery solution of either of the following substances, viz., chlorine, bromine (2 per cent.), iodine, corrosive sublimate (1 per cent.), permanganate of potash (5 per cent.), and osmic acid (1 per cent.). They were also destroyed after longer periods by the following, viz., ether, oil of turpentine, hydrochloric acid, chloride of iron (5 per cent.), arsenious acid (1 per cent.), chloride of lime (5 per cent.), sulphide of ammonium, formic acid, chloropicrin, and quinine (1 per cent. solution in water with hydrochloric acid). It appeared, however, that the destructive power upon spores of substances in the form of vapour is in some cases increased by elevation of temperature. Thus spores of the bacilli found in garden earth were killed in two hours by exposure at a temperature of 176° F., to the vapour of bisulphide of carbon, although neither this temperature in dry air, nor the vapour of bisulphide of carbon in equal concentration at ordinary temperatures, had any destructive action on spores.

With dry heat.

The experiments of Koch and his fellow workers with hot air were made in apparatus consisting of a cylindrical or rectangular vessel of cast-iron heated by steam at a pressure up to six atmospheres in a closed coil of copper pipe.

The results of these experiments are thus summed up by the authors:—

1. Bacteria free from spores cannot withstand an exposure of one and a half hours to a temperature a little over 212° F. in hot air.

2. Spores of mildews require for destruction a temperature of 230°–239° F. for an hour and a half. On Disinfection by Heat; by Dr. Parsons.
3. Spores of bacilli are only destroyed by remaining three hours in hot air at 284° F.
4. In hot air the temperature penetrates so slowly into articles to be disinfected that after three or four hours' heating to 284° F. articles of moderate dimensions, *e.g.*, small bundles of clothes, pillows, &c., are not disinfected.
5. By the heating for three hours to 284° F. necessary for the disinfection of such objects most materials are more or less injured.

And with steam. The experiments with steam were made partly in a closed steam cooking-pot; but the authors prefer an apparatus devised by them, consisting of a boiler below, and above of a cylindrical tin vessel covered with non-conducting material, and closed by a lid having a hole sufficiently large to allow the escape of steam, but not the entrance of currents of cold air: through this apparatus a current of steam was allowed to pass. The steam, not being under pressure, had an initial temperature of 212° F.; but the authors state that they find, contrary to the common belief, that a higher initial temperature may be obtained in the steam by adding saline substances to the water in the boiler, so as to raise its boiling point.

The results obtained with steam were strikingly superior to those with dry heat. It was shown that an exposure of five minutes to steam, at 212° F.,* was sufficient to kill the spores of the anthrax bacillus, and one of 15 minutes to kill those of the bacilli contained in garden earth. Moreover, the penetration of the heat into articles exposed to steam took place far more quickly than into the same articles when exposed to dry heat.

With regard to the discrepancy between the results of Koch's experiments and the commonly-received opinion of the efficacy of dry heat as a disinfectant, the remark must be made that the infective materials upon which the experiments were made are not those for the destruction of which disinfecting processes are ordinarily used, and the failure to sterilise them does not therefore contradict the commonly entertained belief of the efficacy of dry heat for the destruction of the perhaps more volatile and unstable contagia of scarlet fever and small-pox.

In the case, moreover, of the organisms contained in garden mould, which proved the most difficult of destruction of any, it must be remembered that earth is a very bad conductor of heat; it is used for covering steam boilers to prevent waste of heat, and water-pipes are buried to prevent their freezing. Even the prolonged heat of summer and cold of winter penetrate but a small distance into the ground, as shown by the uniform temperature of the water in wells of moderate depth. The longer exposure necessary to kill the spore-bearing bacilli in garden earth may therefore have been due to the slowness with which the heat reached them.

Dr. Waller's summary. The following tables of the degrees of heat which have been found sufficient and insufficient for the destruction of various contagia, &c., is taken from the article on Disinfectants by Edwin Waller, Ph.D., of New York, in Buck's Hygiene, Vol. II., p. 550.

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* In another experiment exposure for 10 minutes to steam at 203° F. sufficed to kill anthrax spores.

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1.—*Virus, &c., destroyed.*

Virus, &c., experimented on.	Temperature, F.	Time.	Remarks.	Observers.
Putrefactive fermentation.	136°	- - -	- - -	Cohn.* Beitrage zur Biologie der Pflanzen. Heft. 3, p. 30.
Ditto ditto -	140	- - -	- - -	Eidam. Ibid., p. 208.
Lower organisms -	266	- - -	Dry heat -	Paris Commission of Academy of Sciences.
Ditto -	230	- - -	Moist heat -	
Vaccine - - -	180	4 hours -	- - -	Henry, Phil. Mag. X., 1831.
Ditto - - -	172	2 do. -	- - -	Ditto.
Ditto - - -	150	2 do. -	- - -	Ditto.
Ditto - - -	140	3 do. -	- - -	Ditto.
Ditto - - -	194–203	34 minutes	- - -	Baxter. Report of Medical Officer of Privy Council, 1875.
Ditto - - -	185–194	46 do.	- - -	Ditto ditto.
Most infectious diseases	112–140	- - -	- - -	Erdt. Veterinaer Polizei. Sorau, 1865, p. 11.
Glanders - -	134	- - -	- - -	Ditto.
Hydrophobia - -	134	- - -	- - -	Ditto.
Scarlet fever - -	204	- - -	- - -	Henry.
Small-pox - -	230–250	6 hours -	Dry heat -	Various health officers in Great Britain. Circular of Dublin Health Department regarding the disinfection of clothes of small-pox patients. June 1778 (? 1878).
Anthrax (blood) -	118½	15 minutes	Moist, diluted -	Davaine. Comptes Rendus, Sept. 29, 1873.
Ditto -	122	10 do.	Ditto ditto -	Ditto.
Ditto -	124	5 do.	Ditto, undiluted	Ditto.
Virus of putrid blood -	320	4 do.	- - -	Felz. Ibid. LXXIV., 953.

* In this article Dr. Cohn shows that although the bacterium termo of putrefaction is invariably killed by a temperature of 100° F., the bacillus subtilis found in hay infusion is not destroyed by boiling for 15 minutes, and is destroyed with certainty only by boiling for two hours or more. The difference in behaviour between the two organisms Dr. Cohn shows to be due to the possession by the bacillus of highly resisting spores; the uncertainty in the results of boiling for different periods being attributable to the varying extent to which spore-formation has gone on in different cases.—H. F. P.

2.—*Virus, &c., not destroyed.*

Virus, &c., experimented on.	Temperature, F.	Time.	Remarks.	Observers.
Putrefactive fermentation.	122°	- - -	- - -	Eidam.
Vaccine - - -	120	3 hours -	- - -	Henry.
Ditto - - -	167–176	47 minutes	- - -	Baxter.
Anthrax (blood) -	212	5 do.	Dry - -	Davaine.
Virus of putrid blood -	176	- -	- - -	Felz.

Vallin (Traité des Désinfectants et de la Désinfection, 1883, p. 238), in reproducing this table, remarks that many of the assertions therein contained are open to question.

On the other hand, Panum (according to Presl, Prophylaxis der übertragbaren Krankheiten, p. 85, Vienna, 1881), finds that septic liquids resist much higher temperatures, as a heat of 320° F. has not sufficed to take away their infectious properties.

II.—*Experiments on the Degree and Duration of Heat necessary for Disinfection.*

Infective materials chosen for experiment.

The following experiments were made in conjunction with Dr. Klein, who furnished the infective materials, and who, after these had been exposed to disinfecting processes by me, tested the results by inoculation

on animals. Control inoculations with unheated portions of the same materials were also in all cases made. On Disinfection by Heat; by Dr. Parsons.

The following were the infective materials employed :—

1. Blood of guinea-pig dead of anthrax, containing bacillus anthracis without spores.
2. Pure cultivation of bacillus anthracis in rabbit broth, without spores.
3. Cultivation of bacillus anthracis in gelatine, with spores.
4. Cultivation of bacillus of swine fever (infectious pneumo-enteritis of the pig) in pork broth.
5. Tubercular pus, from an abscess in a guinea-pig which had been inoculated with tubercle.

The life-history of the bacillus anthracis,* the mode of preparation of cultivations of it, with and without spores, and the results of the inoculation of such cultivations into rodent animals, are minutely described by Dr. Klein in the Annual Report of the Medical Officer to the Local Government Board for 1881, p. 172, et seq.

Infectious pneumo-enteritis of the pig (swine fever) is fully described in the report of the Medical Officer to the Local Government Board for 1877 by Dr. Klein, who shows that the disease is caused by the introduction into the body of the affected animal of a specific bacillus; that among pigs it is highly infectious, the contagium being transmissible through the air, and persisting in infected buildings in a similar manner to the observed behaviour of small-pox and scarlet fever among human beings; and that the disease, though not transmissible to mankind, can be inoculated upon rodents, although in them it is not contracted by infection received through the air.

With regard to tuberculosis, Dr. Klein states that this disease may be produced in rodents with certainty by the inoculation of tuberculous pus, but not by the inoculation of non-tuberculous matter; the results formerly recorded by Dr. Burdon Sanderson, Wilson Fox, and others, viz., that tuberculosis could be produced in guinea-pigs by the inoculation of non-specific irritants, not being obtainable when due precautions are taken to exclude the casual introduction of tubercle.

The mode of procedure in exposing the materials to heat was as follows: strips of clean flannel were steeped in the respective infective fluids, dried in the air, wrapped separately and loosely in a single layer of thin blotting paper, and suspended in the centre of the apparatus in company with a thermometer, so placed that its bulb was close to the packets of infected material.

Experiments with Dry Heat.

The experiments on the destructive power of dry heat upon contagia were made in a copper hot-air bath, or more often in an arrangement constructed of large-sized flower pots. Under an inverted pot standing on three blocks a Bunsen burner furnished with a rose was placed. Upon this, bottom to bottom, stood a second pot in such manner that the holes at the bottom of the two pots coincided, and the heated air could pass up through from the lower into the upper, a saucer full of sand being placed on supports at the bottom of the second pot in such manner as to spread abroad the ascending current of hot air.† A third pot of equal size to the second rested on it mouth downwards, rim to rim, the two Mode of exposure.

* A summary of Dr. Koch's researches on the relation of the bacillus anthracis to the etiology of splenic fever is given by Dr. Klein in the Report of the Medical Officer to the Local Government Board for 1877, pp. 208–9.

† The equal diffusion of the hot air was found to be aided by placing above this a perforated copper diaphragm.

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together forming one chamber, which was wrapped in flannel to keep in the heat. Through the hole in the bottom of the uppermost pot the materials to be subjected to heat were let down, and suspended by wires at a depth of six inches from the top, a thermometer (not registering) being inserted in the hole in such manner that its bulb was in proximity to the suspended objects. By watching this thermometer and regulating the supply of gas, or by the use of a Bunsen thermo-regulator, the temperature of the chamber could be maintained within a variation of a few degrees.

Experiments with moist air.

In view of the superior efficacy of steam, to be hereafter spoken of, both in the destruction of infective matters and in the penetration of badly conducting materials, some experiments were made with hot moist air in the hope that it might be found possible to obtain the advantages of the use of steam without its drawbacks. This hope, however, was not realised, it being found by Dr. Klein that the spores of the bacillus anthracis at all events retained their vitality equally well in heated air, whether this were dry or moist.

In these experiments either a saucer of water, replenished from time to time through a long funnel, was placed at the bottom of the middle pot in the above arrangement, or steam evolved in a flask was led into the chamber by a pipe.

An attempt was made to measure the degree of humidity of the air in these experiments by suspending in the chamber two maximum-registering thermometers arranged side by side, one of them having its bulb covered with gauze kept moist by dipping in a phial of water, as in the wet-and-dry-bulb arrangement employed by meteorologists. I find, however, that there are no tables or formulæ in existence by which the degree of humidity of the air corresponding to a given difference between the wet and dry bulb thermometers at these high temperatures can be ascertained. I am informed also that the conditions in a heated chamber are so different from those met with in meteorological practice, and there are so many sources of error affecting the readings, that it is doubtful whether the relative humidity of the air could with any degree of accuracy be obtained in this way.

The following are the results of the inoculations made by Dr. Klein with infected materials heated in air :—

A.—*Experiments with Anthrax.*

Results of experiments with dry heat on anthrax bacillus: Without spores.

1. *Blood of Guinea-pig, dead of Anthrax, exposed on Strips of Flannel to Dry Heat of* 212°–218° *F. for the following periods :—*

Duration of Exposure.	Animals Inoculated.	Result.
(*a.*) For 1 hour,	1 guinea-pig	Remained well.
(*b.*) For 5 minutes	ditto	Remained well.

With spores.

2. *Spores of Anthrax Bacillus, exposed on Strips of Flannel to Dry Heat of* 212°–218° *F.*

Duration.	Animals Inoculated.	Result.
(*a.*) For 5 minutes,	1 guinea-pig	Died of typical anthrax within 48 hours, (*b*) a few hours after (*a*).
(*b.*) For 1 hour	ditto	Died of typical anthrax within 48 hours, (*b*) a few hours after (*a*).
(*c.*) For 2 hours	ditto	Do. after 48 hours.
(*d.*) For 4 hours	ditto	Remained well.

N.B. (*c*) and (*d*) were heated in a water-bath, the outer chamber of which contained a saline solution boiling at 220° F.

3. *Experiments with Spores of Anthrax Bacillus, after exposure on Strips of Flannel to higher Degrees of Dry Heat.* On Disinfection by Heat; by Dr. Parsons.

Duration.	Animals Inoculated.	Result.
(*a.*) For 4 hours, 245°–252°, - (in Ransom's oven).	1 guinea-pig	Remained well.
(*b.*) For 2 hours to 245° (in do.)	ditto	
(*c.*) For 1 hour to 245° (in do.)	ditto	
(*d.*) For 1 hour to 280°–290°, in pots,	ditto	

4. *Experiments with Spores of Anthrax Bacillus, exposed on Strips of Flannel to Moist Heat.* With moist heat.

Duration.	Animals Inoculated.	Result.
(*a.*) For 2 hours to moist heat, 212°–216° F.,	1 guinea-pig	Died of anthrax after 48 hours.
(*b.*) For 1 hour to moist heat, 212°–216° F.	ditto	
(*c.*) For 1 hour to very moist heat,* 212°–220° F.	ditto	

B.—*Experiments with Artificial Cultivation of Swine Fever after exposure on Strips of Flannel to Dry Heat of* 212°–218° *F.* On swine fever bacillus.

Duration.	Animals Inoculated.	Result.
(*a.*) For 1 hour -	1 rabbit	Remained well.
(*b.*) For 5 minutes,	ditto	Died of swine fever after 17 days.

N.B.—The normal time of death of a rabbit, after inoculation with swine fever cultivation, is between five and eight days.

C.—*Experiments with Tuberculous Pus, exposed on Strips of Flannel to Dry Heat as under :—* On tuberculous pus.

Duration and Degree.	Animals Inoculated.	Result.
(*a.*) Five minutes to 220° F.	1 guinea-pig	Remained well five months later.
(*b.*) ¼ hour ditto	ditto	ditto.
(*c.*) ½ hour ditto	ditto	ditto.
(*d.*) 1 hour ditto	ditto	ditto.
(*e.*) Ditto to 212°–220° F.	ditto	Remained well seven months later.
(*f*) 2 hours to 212°–216° F.	ditto	Both guinea-pigs died of anthrax accidentally contracted.
(*g.*) Ditto to 212°–240° F.	ditto	

The foregoing results, as far as regards anthrax, are far more favourable to the efficacy of dry heat as a disinfecting agent than those of Koch. Remarks on above results.

It appears that the spores of the bacillus anthracis lost their vitality, or at any rate their pathogenic quality, after exposure for four hours to a temperature a little over the boiling point of water (212°–216°), or for

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* In this experiment the wet bulb thermometer registered 190°. On comparing this reading with those given on pp. 262 and 271 it will be seen that a difference of only 30° between wet and dry bulb thermometers when the dry bulb is so high as 220° indicates a high degree of humidity of the air.

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one hour to a temperature of 245° F. Non-spore-bearing bacilli of anthrax and of swine fever were rendered inert by exposure for an hour to a temperature of 212°–218°, and even five minutes exposure to this temperature sufficed to destroy the vitality of the former, and impair that of the latter.

As none of the infectious diseases for the extirpation of which measures of disinfection are in practice commonly required are known to depend upon the presence of bacilli in a spore-bearing condition, it may be concluded that, as far as our knowledge goes, their contagia are not likely to retain their activity after being heated for an hour to 220° F. I do not, of course, mean that it is sufficient to expose, say, a pillow for an hour in a chamber heated to this temperature, for dry heat, as we shall see, penetrates but slowly into such articles, but that an article which has been heated throughout to 220° F. for an hour is not likely to retain infection.

Experiments with Boiling Water.

Experiment with spores of bacillus anthracis subjected to boiling.

The following experiments were made by Dr. Klein :—

Portions of a cultivation of anthrax bacillus containing spores were boiled in a half per cent. solution of common salt for short periods of time with the following results :—

Duration of Boiling.	Results.
1 minute - - -	Guinea-pigs inoculated all remained well.
2 minutes - - -	
5 minutes - - -	

It was found that the boiling point of this very dilute brine did not differ from that of distilled water to an extent appreciable by an ordinary thermometer.

The above results being so satisfactory, it was not considered necessary to repeat the experiments with the less-resisting contagia of swine fever and tubercle.

It may be inferred that the contagia of the ordinary infectious diseases of human beings are not likely to retain their activity after boiling for a brief period in water.* This inference is in accordance with the results of practical experience.

Dr. Russell, Medical Officer of Health for Glasgow, says in a letter :—
" For many years I have used no other disinfecting method for washable
" articles than boiling one quarter to three quarters of an hour by steam
" with soda and soap. I concluded this was sufficient, because, though
" we threw small-pox, typhus, enteric, scarlet, &c., all into one witches'
" cauldron, I never heard of any intercommunication or continuity of
" infection." (See also a paper on disinfection by Dr. Russell in the Glasgow Medical Journal, December 1884.)

Experiments with Steam.

Method of experimenting.

The experiments with steam at atmospheric pressure were made in an improvised apparatus similar to that employed in Dr. Koch's researches. It consisted of a tin cylinder 14 inches long and 4 inches in diameter,

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* It has been proved by the experiments of Roberts, Cohn, Pasteur, and others that certain organic substances, as neutralised hay infusion, peas, and milk, require for complete sterilisation prolonged boiling or even in some instances exposure to a moist temperature above 212° F. In these cases the organisms which make their appearance after exposure to heat of shorter duration or lower degree are bacilli, which form spores highly retentive of vitality. Of diseases affecting the human species, anthrax is the only one of which it is established that it is connected with the presence of microzymes possessing this persistent spore form.

wrapped in felt to diminish loss of heat. In the bottom a hole was made, and by means of corks and a short piece of pipe, the cylinder was connected with a tin flask serving as a boiler. A false bottom was fixed in the cylinder just above its base, with a view to the more even distribution of the heat. The upper end of the cylinder was closed with a lid, having a hole in the centre just large enough for the escape of steam and the introduction of a thermometer. The thermometer was held in place by passing its stem through a perforated cork which rested on the lid, so that by sliding the cork (which moved stiffly) up or down the stem, the bulb of the thermometer could be inserted into the cylinder and held at any required depth. It was found that a thermometer registered the same, whether the bulb were 6 inches or 11 inches from the top; but that when the bulb was only 1 inch from the top (the lid not being covered with felt) it marked 1½° F. lower. The test objects were hung at a depth of about 6 inches.

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Steam above 212° F.

An attempt was made to get a higher temperature than 212° F. in the cylinder by superheating the steam. To this end the cylinder and boiler were connected by a piece of metal pipe 1 foot long, bent so that the ends were vertical and the intermediate part nearly horizontal; this part was heated with a spirit lamp. These means, however, were insufficient to raise the temperature inside the cylinder above 212° F. Nor was a higher temperature obtained in the cylinder when a saline solution (25 per cent. common salt) was used instead of water in the boiler, as recommended by Koch.

By saline solutions.

In the memoir of Koch, Gaffky, and Löffler, on Disinfection by Steam, p. 19, the following statements occur:—

"In the text book of physical and theoretical chemistry of Buff, Kopp, and Tamminer (1 Abtheilung, s. 24) we find the following paragraph:—

"'It has long been believed that the temperature of the steam which disengages itself from boiling saline solutions is just the same as of that which under the same pressure is given off from pure boiling water. It is, however, now established beyond doubt that the temperature of such steam, if all cooling of it be avoided, is equal to that of the boiling liquid.'

"Magnus (Gmelin-Kraut, Handbuch der anorganischen Chemie, Bd. 1, s. 570) has made confirmatory experiments on the temperature of steam given off from saline solutions, and has found that such steam does not indeed quite attain the temperature of the boiling saline solution, but is nevertheless considerably hotter than that given off from pure water. From a solution of calcium chloride which had a boiling point of 107° C. (224·6° F.) Magnus obtained steam of 105·25° C. (221·5° F.), and from a solution boiling at 116° C. (241·8° F.) steam of 111·2° C. (232·2° F.)."

I am quite unable to account for the discrepancy between these statements and the results of the following simple experiment:—

A flask holding about 6 ozs. was half filled with saturated brine, containing undissolved salt (Na Cl). To check loss of heat the neck and the upper half of the flask down to the level of the liquid were wrapped in several layers of flannel. The brine was then boiled over a gas flame, when a thermometer placed in the neck of the flask, with its bulb at the junction of the neck and body, *i.e.*, about 2 inches above the boiling liquid marked 212° F. On lowering the bulb about an inch, within reach of the splashes from the boiling brine, which bumped and spirted very much, the mercury rose to 213° F., but on lowering the bulb into the brine, it at once went up to 228° F.

On repeating the experiment with pure water, the thermometer, with the bulb at the bottom of the neck of the flask, stood at 212°, exactly at the same point as with the brine. With its bulb in the boiling water the thermometer marked 213°·3, the excess of 1°·3 being probably due to the cohesion between the steam and the glass vessel.

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By pressure.

A temperature above 212° F. is, however, readily obtained in steam by confining it under pressure. The pressure of steam in contact with water at any given temperature is constant, a diminution of pressure being accompanied by a fall of temperature, and vice versâ, according to the following table :—

Pressure in lbs. per square inch above that of Atmosphere.		Temperature F.
0	=	212
5	=	228
10	=	240
15	=	251
20	=	261
25	=	269
30	=	276
35	=	282
40	=	288
45	=	294
50	=	299

Superheating.

"Dry steam," however, *i.e.*, steam not in contact with water, may by appropriate means be *superheated*, *i.e.*, it may be raised to a temperature higher than that corresponding in the above table to the pressure. When water is present an increase of temperature converts a fresh portion of it into steam, and so raises the pressure, but the application of heat to dry steam merely increases its volume according to the ordinary law of expansion of gases by heat.

At a temperature of 250° F., equalling a pressure of about 15 lbs. to the inch above that of the atmosphere, the action of steam on many animal substances is very marked; leather is shrivelled up and the thinner sorts converted into a gelatinous substance; the caterpillars of a moth infesting carpets were burst down the back and the eggs converted into a minute drop of structureless jelly.

The following are the results, as furnished to me by Dr. Klein, of experiments with infective materials exposed to steam at 212° F. in the manner before described, for periods of varying length.

Results of experiments with steam on anthrax.

A.—*Experiments with Anthrax.*

1.—*With artificial Culture of Bacillus Anthracis (free from spores).*

Without spores.

	Mode and Duration of Exposure.		Animals Inoculated.	Result.
(*a.*)	On flannel for	5 minutes,	1 guinea-pig	All animals remained well.
(*b.*)	Ditto	¼ hour	ditto	
(*c.*)	Ditto	½ hour	ditto	
(*d.*)	Ditto	1 hour	ditto	
(*e.*)	In capillary tube for 1 hour		ditto	

2.—*With fresh Blood of Guinea-pig dead of Anthrax after exposure to Steam.*

	Mode and Duration of Exposure.		Animals Inoculated.	Result.
(*a.*)	On flannel for	5 minutes,	inoculated 1 guinea-pig	All animals remained perfectly well.
(*b.*)	Ditto	¼ hour	ditto	
(*c.*)	Ditto	½ hour	ditto	
(*d.*)	Ditto	1 hour	ditto	
(*e.*)	In capillary tube for 1 hour		ditto	

3.—*With Spores of an old Culture of Bacillus Anthracis.*

With spores.

(*a.*)	On flannel for 1 hour, 1 guinea-pig	-	Remained well.
(*b.*)	On flannel for ½ hour ditto	-	Remained well.
(*c.*)	On flannel for ¼ hour ditto	-	Remained well.
(*d.*)	On flannel for 5 minutes ditto	-	Had swelling at seat of inoculation 6 days after, but remained well.

B.—*Experiments with artificial Cultures of Bacillus of Swine Fever.*

On swine fever,

(*a.*)	On flannel for 5 minutes,	inoculated	2 mice and 1 rabbit	-	All animals remained well.
(*b.*)	Ditto ¼ hour	ditto	ditto	-	
(*c.*)	Ditto ½ hour	ditto	1 rabbit	-	
(*d.*)	Ditto 1 hour	ditto	1 ditto	-	
(*e.*)	In capillary tube for 1 hour	ditto	1 ditto	-	

C.—*Experiments with Tuberculous Pus from Guinea-pig exposed to Steam.*

On tubercle.

(*a.*)	For 5 minutes on flannel, 1 guinea-pig (inoculated June 25th, 1884)			-	Remained well February 7th, 1885.
(*b.*)	For ¼ hour	ditto	ditto	-	Remained well February 7th, 1885.
(*c.*)	For ½ hour	ditto	ditto	-	Died on July 25th, 1884, from unknown cause, not tubercle.
(*d.*)	For 1 hour	ditto	ditto	-	Remained well February 7th, 1885.
(*e.*)	For 1 hour in capillary tube	ditto	ditto	-	Remained well February 7th, 1885.

The results of the above experiments are conclusive as to the destructive power of steam at 212° F. upon all the contagia submitted to its action; in one instance only was there room for suspicion that the disinfection had not been complete; this was in the case of the highly resisting anthrax spores, exposed to steam for five minutes only. On the other hand, the animals inoculated with unheated portions of the same materials all died.

These results are in accordance with those of Koch, Gaffky, and Löffler, and it may be considered established that the complete penetration of an object by steam heat for more than five minutes is sufficient for its thorough disinfection.

In view of the above satisfactory results it was not deemed necessary to make any experiments as to the disinfecting power of steam at higher temperatures or under pressure; its efficacy may be taken for granted.

Experiments on Lice.

On lice.

In view of the frequent employment of heat for the destruction of vermin in clothing, it was thought desirable to make some observations on this point in connection with the present inquiry.

It is easy to recognize when the adult insects have been destroyed; they become shrivelled and motionless, and relax their grasp, so as to

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fall off the garment. Eggs of lice exposed to dry heat are shrivelled; those exposed to steam or boiling water are at first distended and opaque white, afterwards becoming shrivelled and horny. In some of the earlier experiments portions of a shirt infested with ova of lice (obtained from a casual ward) were exposed to heat in the same way as the strips of flannel, and were subsequently tested by Dr. Klein by incubation in moist air, under a bell glass in a warm chamber. It was found, however, that the eggs of lice treated in this way failed to develop, even when they had not previously been exposed to heat. It was subsequently found that the eggs of lice could be conveniently hatched by tying up tightly in muslin a small piece of the garment on which they were deposited, and carrying it about for a week or two in a warm pocket. Tested in this way no development was found to take place in eggs of lice which had been exposed for one hour to 300° F. dry heat, for one hour to 230° F. dry heat, or for 10 minutes to steam at 212° F., or which had been boiled for five minutes in water.

I did not, however, ascertain what is the maximum temperature which lice or their eggs will bear with impunity. I have frequently been told by officers of workhouses that lice will crawl alive out of boiling water, but are killed by soaking in cold water. I will not attempt to explain the paradox, as I feel sure that the first proposition must be based on some error of observation. In a tramp's garment which was boiled in water for five minutes in my presence, careful search brought to light plenty of dead specimens of lice, but no living ones, and the eggs tested in the way previously described failed to develop.

Necessity for heat to penetrat objects to be disinfected.

III.—*On the Penetration of Heat into Articles submitted to Disinfection.*

In order to secure the thorough and certain disinfection by heat of porous articles likely to retain infection, such as clothing and bedding, it is necessary that the heat should be made to permeate the articles in every part to such a degree and for such a length of time as to destroy all infectious matter with which they may be imbued. It is true that the outer casing of such articles as pillows and mattresses, coming into closer contact with the body of the patient, is more liable to become soiled with infectious matters than the inner parts, and for the same reason is more likely to be the carrier of infection to other persons; but it would not be safe to assume that infection was confined to such external coverings or to the superficial layers of the stuffing, more especially when the articles have been soaked with liquid discharges. Furthermore, the movement of air must not be forgotten which takes place within the substance of such articles as beds and pillows when pressed by, or relieved from, the weight of a person's body. This movement would lead to the introduction of infective particles into the interior of such articles when in use by an infected person, and afterwards, in spite of the disinfection of the more superficial layers, would lead to the delivery of such infective particles to the surface, so as to do harm to a person subsequently using the bed or pillow.

Modes of propagation of heat.

Heat, it is well known, may be propagated in several different ways:

Radiation.

1st. It may be radiated from a heated solid body. In this form it travels in straight lines in the same manner as light (with which indeed it is considered by physicists to be in essence identical) and may pass

through a transparent medium without heating it. Gases especially, as air, absorb or emit little radiant heat, and the less in proportion as they are free from suspended solid particles or watery vapour. Thus the sun's rays which warm the earth have passed through the intensely cold regions of space and of the upper atmosphere. On the other hand, solids, especially if rough or dark coloured, absorb and give off radiant heat with great facility.

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Conduction.

2nd. Heat is also conducted through the substance of bodies, especially solid bodies. The conducting power of different substances for heat varies greatly, being greatest in dense and homogeneous substances, such as metals, and least in those which are light and porous in texture so as to present many alternating layers of air and solid.

Convection.

3rd. Heat is also conveyed through fluids, liquid or gaseous, by currents set up by the alteration in density due to expansion by heat. When heat is applied to a fluid the layers next the heated surface, becoming warmed, expand and are rendered specifically lighter; they thus ascend, being displaced by relatively heavier portions, which in their turn become heated and ascend.

Difference between radiant and conveyed heat.

There is a marked difference between the distribution of temperature in a chamber heated primarily by radiant heat and in one heated by the admission of hot air (or steam). Radiant heat is most intense close to its source, diminishing rapidly (as the square of the distance) as we recede therefrom. Also it does not turn corners, and thus objects lying behind others are screened from it, except so far as it may be reflected upon them from other surfaces. The rays strike the walls of the chamber, and objects therein, so that these are more highly heated than the air, which becomes heated only secondarily by contact with them.

On the other hand, if air already heated, or steam, be admitted into a chamber the temperature tends to equalise itself in the different parts, and the walls and solid contents of the chamber do not become hotter than the air.

Effect of non-conducting materials in screening off heat.

It has been well remarked that bedding, blankets, &c., are the highest outcomes of the ingenuity of man to check the passage of heat from one side of the object to the other. It is no wonder, therefore, that they should be found difficult of penetration by heat. Even thin layers, however, of badly conducting substances interpose a considerable barrier to the passage of dry heat. As regards radiant heat this is notorious; it is well known what a slight shelter, *e.g.*, a wide-meshed net, will screen off frost or prevent the formation of dew. The following experiment was made to ascertain how far, in the experiments of Dr. Koch previously mentioned, as well as in those undertaken for this report to ascertain the degree of heat necessary for the destruction of contagia, the enclosing of the infective objects in blotting paper or test tubes plugged with cotton wool hindered the full access of heat to them.

Two similar registering thermometers were taken; the bulb of one was tied up in a single layer of thin white blotting paper, that of the other was placed in a test tube $\frac{5}{8}$ inch wide in such a manner as not to touch the sides, and a plug of white cotton wool 1 inch deep was pushed into the tube around the stem of the thermometer, but not as far as the bulb. Both the paper and cotton wool were previously dried. The two thermometers together with another with bare bulb were then hung up in the hot-air bath of pots previously described, in which a perforated copper false bottom was placed with a view to cutting off rays of heat from the bottom and distributing the heat uniformly among the air

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entering the chamber. Heat being applied, the thermometers were read half-hourly as follows:—

Time from Lighting.	Readings of Thermometer with Bulb		
	Bare.	In Paper.	In Tube.
	° F.	° F.	° F.
½ hour - - -	162	147	151
1 hour - - -	212	193	196
1½ hour - - -	234	213	219
2 hours - - -	242	236	238
2½ hours - - -	244	244	244

The following experiment was made with a thermometer having the bulb covered with a single layer of blanket and placed in the hot air bath already heated :—

Time from placing in Hot Air Bath.	Thermometer with Bulb bare.	Thermometer with Bulb in Blanket.
	° F.	° F.
½ hour - - -	246	231
1 hour - - -	260	250
1½ hour - - -	266	254
2 hours - - -	268	263
2½ hours - - -	268	264

Experiments with pillows, &c.

The details of experiments made by me with larger articles are narrated under the headings of the different apparatus in which they were made. As a test object a flock or feather pillow weighing 3–4 lbs. was usually employed, a registering thermometer being pushed into the middle.

In all cases the apparatus was already heated when the pillow was placed in it, but the opening of the door necessarily caused a temporary fall in the temperature.

The following table gives the results of experiments with pillows. As, however, the same pillows were not used in all the experiments the results are not comparable as showing the relative efficiency of the different apparatus. There does not appear to be very much difference between the conducting power of flock and feathers, but the tightness or looseness with which the materials are packed makes a great deal of difference to the result.

1.—*Dry Air.*

Description of Pillow.	Weight.	Temperature to which exposed.	Apparatus.	Time.	Temperature in Centre.	Scorched or not.
	Lbs.	° F.		Hours.	° F.	
Feather - -	5	312	Leoni -	½	140	Scorched.
Flock - -	4	280	Langstaff	2	147	Ditto.
Feather (tight) -	3	344	Scott -	4	138	Ditto.
Flock - -	4	?	Fraser -	1	134	Ditto.
Feather (loose) -	3	(above	Ditto -	1	275	Ditto.
Flock - -	6	275).	Ditto -	2	138	Ditto.
Flock - -	4	?	Ditto -	6	298	Ditto.
Flock - -	4½	318	Ditto (portable).	1	136	Ditto.
Flock - -	3	250-260	Ransom -	5½	227	Not scorched.
Horsehair - -	?	276	Scott -	1	149	Not scorched.
Feather - -	5¼	290	Taylor -	1	122	Not scorched.

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2.—*Moist Air.*

Description of Pillow.	Weight.	Temperature to which exposed.	Apparatus.	Time.	Temperature in Centre.	Readings of Wet Bulb Maximum Thermometer.
	Lbs.	° F.		Hours.	° F	° F.
Flock - -	4	220–240	Bradford	2½	217	184
Flock - -	3¾	268	Ditto -	1	252	212
Feather - -	5½	295	Taylor -	1	162	192
Flock - -	4½	299	Fraser (portable).	1	188	189
Flock - -	4½	264	Ditto -	1	209	192

3.—*Steam.*

Pillow.	Weight.	Temperature to which exposed.	Apparatus.	Time.	Temperature in Centre.	Pressure of Steam above that of Atmospheric.
	Lbs.	° F.			° F.	
Feather (tight) -	6½	251	Lyon -	½ hour	185	15 lbs. constant.
Same -	Same -	251	Ditto -	½ hour	212	15 lbs., once relaxed and reapplied.
Feather - -	3½	251	Ditto -	½ hour	237	
Flock - -	3½	240	Benham -	2 min.	171	10 lbs.
Flock - -	3½	240	Ditto -	10 min.	234	10 lbs.
Feather - -	3½	240	Ditto -	10 min.	234	10 lbs.
Feather - -	2¾	212	Bradford -	10 min.	182	——
Feather - -	2¾	252	Ditto -	½ hour	251	22 lbs. (?)

The above examples show how difficult it is to secure the penetration of a dry heat sufficient for disinfection into the interior of such an article as a pillow. It was only effected by either employing a very high degree of heat or by continuing its employment during many hours, the length of exposure compensating for a lower degree of heat.

The following table is taken from a paper by Dr. W. H. Ransom, F.R.S., "On the mode of Disinfecting by Heat," in the British Medical Journal, September 6th, 1873, and refers to experiments made in his self-acting regulating disinfector:—

No.	Name, Thicknesss, and Condition of Sample.	Heat used. ° F.	Time heated.	Results.		
				Heat of Inside.	Loss of Weight.	Singed or not.
			Hours.	°		
1	Horse-hair pillow, 5 ins. thick, normal moisture.	251–262 (2 operations).	8	247	1/10	Not.
2	The same, nearly dry -	247	2⅘	221	1/40	Not.
3	White blanket, folded in 24 layers, 4½ ins. thick, moist.	248	6¾	214	1/12	A little; not injured.
4	Feather pillow, 5 ins. thick, moist.	241	7⅖	232	1/10	Not.
5	Flock pillow, 5 ins. thick, moist.	237–245 (2 operations).	23	252*	1/10	Not.
6	Horse-hair pillow, 5½ ins. thick, very moist.	293	3½	178	1/8	Singed; injured.
7	The same, much drier -	296	4¾	296	1/17	Ditto ditto.
8	Flock pillow, 5½ ins. thick, moist.	293–300 (2 operations).	10½	280	1/10	Ditto ditto.

* (Footnote by Dr. Ransom.) Perhaps an error in instrument. The inner and outer thermometers in this case may be taken as equal.

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The experiments which I have already so often quoted of Koch and his coadjutors have shown that there is a very great difference between the rate of penetration of heat into badly-conducting articles when the heat is applied in the form of dry heat and in that of steam, the difference being in favour of the latter. The results recorded in the preceding table fully bear out this view, and I have made some other experiments to the same effect.

Superior penetrative power of steam over dry heat.

Three yards of flannel previously dried were wrapped round a registering thermometer, making a roll 12 inches long and 4 inches broad; this was placed in the cylinder before mentioned and exposed for 10 minutes to steam at 212° F. The thermometer registered 212°. The same roll of flannel after drying was placed in the hot-air bath of pots and exposed for an hour to a temperature of 212°. The thermometer inside then registered 130° F.

In the centre of a bale of cotton rags weighing 61 lbs. exposed for six hours in a Fraser's oven to a heat rising from 210° to 272°, a thermometer only registered 118° F., and in a bale of cloth rags similarly exposed only 99°. On the other hand, in a bale of cotton rags weighing 188 lbs. exposed for only one hour to steam at 15 lbs. pressure (=251° F.) in Lyon's machine, a thermometer registered 242°,* and with steam at 30 lbs. pressure in the casing and 15 lbs. in the interior, relaxed every half hour, a temperature of 255° was obtained in two hours in the centre of a bale of woollen rags weighing nearly 5 cwt., (549 lbs.). By a similar exposure of four hours a temperature of 258° F. was obtained in the centre of a press-packed bale of cotton rags weighing 5 cwt.

It cannot be doubted that to procure the penetration by heat of bulky articles of badly-conducting material high pressure steam is the agent *par-excellence.*

The causes of the superior penetrative power of heat in the form of steam over hot air may here be pointed out.

Latent heat of steam.

1st. Probably the most important is the large amount of latent heat contained in steam. To convert 1 lb. of water at 212° F. into steam at 212° F. requires nearly 1,000 times as much heat as it does to raise 1 lb. of water from 211° to 212° F. And conversely, a corresponding amount of heat is liberated when 1 lb. of steam at 212° F. is condensed into water at 212° F. When an object is heated by being placed in hot dry air, not only is no latent heat yielded up to it by the air, but on the other hand, before the object can attain the temperature of 212°, any water which it may contain (and all textile fabrics, even though dried at ordinary temperatures, retain a quantity of hygroscopic moisture) must be evaporated; in this evaporation heat passes into the latent form, and the attainment of the required temperature is thus delayed.

Condensed steam makes way for more.

2nd. When steam penetrates into the interstices of a cold body it undergoes condensation in imparting its latent heat as aforesaid to the body. When condensed into water it occupies only a very small fraction (about $\frac{1}{1300}$) of its former volume. To fill the vacuum thus formed more steam presses forward, in its turn yielding up its heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand hot air in yielding up its heat undergoes contraction in volume, it is true, but only to a very small extent as compared with that undergone by steam in condensing into water. Thus air at 250° F.

* In another experiment with the same bale of rags, exposed for five hours to a temperature of 272° in air without pressure, a temperature in the centre of only 192° F. was obtained.

in cooling to 50° F. would contract to five-sevenths of its previous volume.

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Heat evolved in moistening hygroscopic substances.

3rd. The heat which is evolved in the moistening of a dry porous substance is another source of advantage on the side of steam.

Pouillet (Annales de Chimie II., xx., p. 141) has shown it to be a general law—

1st. That when a liquid wets a solid there is a disengagement of heat.

2nd. That when a solid absorbs a liquid there is a disengagement of heat.

The amount of heat liberated in the incorporation of a liquid into the substance of a solid is much greater than that liberated by mere superficial wetting; this is owing to the multiplication of points of contact. In proportion as a wetted substance is finely divided, the number of particles which are moistened and take part in the evolution of heat is multiplied, while the number is diminished of those which, not being wetted, do not give out heat but absorb it at the expense of others. Hence porous organic substances, as being most finely divided, are those which in moistening evolve most heat. (Chemical reactions attended with the evolution of heat, like the slaking of lime, are of course excluded).

If a clinical thermometer be wrapped up in a few turns of flannel which has recently been highly dried before the fire and cooled, and the roll be held in the mouth and the expired breath forced through it, a temperature considerably over that of the breath will be found to be registered by the thermometer. In such an experiment I found the thermometer to reach 110·6° F., the temperature of the breath as taken by the same thermometer being 99·2.*

If the flannel in which the bulb of the thermometer is wrapped have been dried merely in the air at ordinary temperature and humidity, an elevation of temperature above that of the breath will still be obtained, but of less extent than in the previous case; while if the flannel be damp no elevation at all will be obtained.

The following experiment shows that the same action takes place at higher temperatures.

A thermometer was wrapped in a few rolls of flannel, and was heated in dry air to 220° F. for some time; it was then allowed to cool a little, and as the mercury fell the index was shaken down till it stood at 212° F. The dry roll of flannel was then placed in the tin cylinder before described and exposed for five minutes to steam at 212° F.; at the end of which time the included thermometer was found to register 239° F.

Greater specific heat of steam.

4th. The specific heat of steam is greater than that of air in the proportion of 30 to 23·7, or about 5 to 4; in other words, four volumes of steam in falling 1° (without condensing into water) yield up as much heat to other objects as five volumes of air at the same temperature yield.

* Dr. William Roberts, F.R.S., of Manchester (Temperature of the Breath, Nature, Nov. 18th, 1880, p. 56), states that he has in this way obtained a temperature as high as 115° F. He explains the phenomenon by the setting free of latent heat in the passage of water from the gaseous into the solid form. Pouillet, however, in the memoir quoted, has shown that the heat evolved cannot be derived from this source. If the absorbed water were, so to speak, frozen, it could not be frozen again on cooling below the freezing point, whereas it is found to undergo freezing which is accompanied with the ordinary heat phenomena. Again the amount of heat liberated is very different when different solids are wetted, but it differs little when the same solid is wetted with liquids so different as water, alcohol, oil, and acetic ether.

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Greater diffusive power of steam.

5th. The diffusion of two gases into one another takes place with a velocity inversely as the square roots of their respective densities. The specific gravity of steam, air being = 1, is ·623; hence the rate at which steam would diffuse into air as compared with that at which air would diffuse into steam at the same temperature would be as 100 to 79, or about 5 to 4. Between air and air the rate of diffusion would be equal, or as 4 to 4; thus, excluding the influence of differences of temperature, steam would diffuse into air with a rapidity one-fourth greater than air would.

Effect of pressure.

6th. The penetration of heat in the form of steam is, I believe (though I am aware that this is contrary to the view of Koch) considerably aided by pressure. The following experiments made with a model of Lyon's machine seem to me to prove this.

A registering thermometer loosely wrapped in a sheet of cotton wool and tied was exposed for half an hour to steam at 28 lbs. pressure = 273° F.; the index marked 270°. It stood equally high after exposures of a quarter of an hour and of five minutes, but after an exposure of three minutes only 260° was recorded.

In another experiment a thermometer similarly wrapped and another one naked were placed in the machine and the door loosely closed; steam at 30 lbs. pressure was admitted into the casing, but into the interior of the chamber only sufficient to moisten the air in the chamber. After half an hour the naked thermometer registered 250°, the one in the cotton wool only 217°.

Effects of intermitting pressure.

It has been mentioned that in the experiments with bales of rags the pressure of the steam was not maintained constant, but was relaxed from time to time and reapplied. In this proceeding we have a means of considerably increasing the penetrative power of the steam, by displacing the cold air remaining in the interstices of the material.

A pressure of steam of 15 lbs. to the square inch above that of the atmosphere compresses the air in the interstices of the material to half its original volume, and thus the space originally occupied with cold air becomes partly occupied with hot steam; steam partly mixed with air occupying the interstices near the surface and air those in the centre. Equilibrium of pressure having been obtained, the interchange of air and steam particles, and of temperature, would take place comparatively slowly. On relaxing the pressure, however, the air again expands to its original volume, and thus becomes mixed with the steam, and on the pressure being reapplied the steam is forced further into the interstices. In my description of Lyon's disinfector I have given an account of some experiments illustrating the advantage of intermittent pressure when bulky objects are dealt with.

Greater penetrative effect may be obtained with hot air by moistening it.

Considering the superior penetrative power of steam over hot dry air, it seemed probable *a priori* that hot moist air would be found to possess in some degree a similar advantage over dry heat. The following experiments were made with this view.

A registering thermometer was wrapped in a piece of flannel and exposed in the pots for an hour to dry heat rising to 212°. At the end of the time the thermometer registered 144°.

After an hour's interval the same thermometer was similarly rolled in the same piece of flannel and exposed in the pots for one hour to a temperature which did not rise above 200°, steam from a flask being led in; at the same time a wet-bulb thermometer registered 146°. At the end of the time the thermometer in the roll registered 220°.

The excess of temperature above 212° was doubtless due to the absorption of water by the flannel which had not fully recovered its hygroscopic moisture after the previous experiment. This therefore

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introduces a source of fallacy. It must also be remembered that the introduction of the steam means an extra supply of heat from without. Hence a greater effect is to be expected. However this may be, the experiments to be hereafter mentioned with Fraser's, Bradford's, and Taylor's apparatus seem to show that in practice an advantage can be obtained as regards penetration of heat by the use of air, moistened with watery vapour. Thus in the experiments with Taylor's apparatus two pillows of the same weight and thickness were exposed for the same time to as nearly as possible the same degree of heat, but in one instance the air of the chamber was dry, and in the other it was moistened by a jet of steam from without. The temperature attained in the centre of the pillow in the first case was 122° in the second 162°, or 40° higher.

IV.—*On the Liability to Injury of Articles disinfected by Heat.*

Difficulty of question.

We now come to one of the most difficult and least satisfactory parts of our inquiry, one which requires to be solved not merely by laboratory experiment, but by practical experience on the large scale; which involves technical knowledge of trade processes, and is complicated by questions of pecuniary interest. As before said, if an object cannot be effectually disinfected without being spoiled, or can be so only at a cost approaching the value of the object itself, it will probably be preferable to destroy it rather than to attempt to disinfect it. Even a deterioration in value by no means amounting to actual spoiling of the articles disinfected may be a source of considerable embarrassment to sanitary authorities, by rendering the owners of infected articles unwilling to submit them to disinfection.* Again, if articles cannot be exposed to a temperature sufficient for disinfection without some risk of injury, there is the danger that in order to avoid this risk the articles may not be heated to a temperature sufficiently high or sufficiently prolonged to ensure their being disinfected.

In this report I do not profess to be able to state exactly what degree of heat or mode of manipulation each material will sustain without injury. I can only attempt to set forth some of the general principles to be kept in view, and much must in all cases be left to individual practical experience, both as to the materials operated on and the particular apparatus employed.

Modes in which injury may occur.

We may indicate the principal modes in which injury may occur to articles subjected to disinfection by heat. They differ somewhat in the case of steam from that of dry heat:—

1. Scorching or partial decomposition of organic substances by heat. In its incipient stages this manifests itself by changes of colour, changes of texture, and weakening of strength.
2. Overdrying, rendering materials brittle.
3. Fixing of stains, so that they will not wash out.
4. Melting of fusible substances, as wax and varnish.
5. Alterations in colour, gloss, &c., of dyed and finished goods.
6. Shrinkage and felting together of woollen materials.
7. Wetting.

Overdrying can of course only occur when dry heat is employed, wetting only when steam or boiling water is used. Shrinkage takes place more with steam than with dry heat. Scorching is more liable to

* In reference to this, see an article "On Disinfection," by Dr. J. B. Russell, M.O.H., Glasgow. (Glasgow Medical Journal, Dec. 1884.)

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occur with dry heat than with steam. The other occurrences may happen with heat in either moist or dry form.

Scorching.

1. Scorching occurs with different materials at different temperatures. It occurs sooner in woollen materials, such as flannel and blankets, than with cotton or linen; while horsehair will bear a higher temperature still; in fact the process of curling it for stuffing chairs is effected by exposing it to a temperature of over 300° F.

Most materials will bear a temperature of 250° F. without much injury, but when this temperature is much exceeded signs of damage soon begin to show. Flannel and blankets exposed to steam at 260° for half an hour acquire a distinct yellow tinge, and their tensile strength is somewhat diminished. Exposed to a dry heat of 220° F. for four hours, or a steam heat of 228° for half an hour, white flannel acquired a slight yellow tinge, but its textile strength was not appreciably impaired.

Experiments of Dr. Ransom.

The following are the results obtained by Dr. Ransom (British Medical Journal, Sept. 6, 1873):—

"White wool, cotton, linen, silk, and paper, may be heated to 250° F. for three hours without apparent injury, although the wool will show a faint change in colour, especially when it is new; perhaps this change is not more than the change which new white flannel undergoes when it is washed. The same may be said of dyed wools and printed cotton, and of most dyed silks, but there is one kind of white silk which easily turns brown with this heat, and pink silks of some kinds are also faded by it. The same or even slightly lower temperatures will, if continued for a longer period—seven or eight hours—slightly change the colour of, but not injure, white wool, cotton silk, paper, and grey linen. A heat of 295° F. continued for about three hours more decidedly singes white wool and less so grey and white cotton, and white silk and white paper and linen, both grey and white, but does not, I think, injure their appearance materially. The same heat continued for about five hours singes and injures the appearance of white wool and cotton, grey linen, white silk, and paper, some coloured fabrics of wool, or mixed wool and cotton, or mixed wool and silk."

Of Dr. De Chaumont.

Dr. De Chaumont (Lancet, Dec. 11, 1875), on the other hand, reports as follows:—

1. Woollen articles are more liable to change by exposure to high temperatures than cotton or linen.

2. Woollen articles begin to lose colour after exposure for six hours to a dry heat of 212° F. or after two hours at 220° F. Higher temperature or longer exposure produces proportionately increased change.

3. Cotton or linen fabrics can be exposed for six hours at 212° F., or four hours at 290° F., without perceptible change; six hours at 220° shows distinct change in some cases, and longer exposure or higher temperatures in all cases.

He quotes a letter from Dr. Lake on the working of the gas chamber (Ransom's) at the Southampton Infirmary, from which it appears that repeated heating was found to damage materials; blankets became yellow in appearance, and mattresses very tender, the tick tearing easily.

Of Vallin.

M. Vallin (Traité des Désinfectants, p. 431), as the result of his experiments, states that it is almost impossible to preserve the brilliant whiteness which woollen tissues have when new, but that exposure for two hours to 230° F. does not give them a deeper yellow tint than does a first washing in hot water. A washed piece of flannel, submitted to this temperature for three hours, does not show any difference from an unheated portion of the same (washed) material. But above 239° F., and

still more above 248° F., the difference becomes marked when the temperature has been maintained at least two hours.

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Tissues of cotton and linen are not changed appreciably in colour by a temperature of 230°–239°; the tint only begins to change at 257° F., continued for several hours. He finds that the resistance of woollen cloth only began to be decidedly impaired at 302° F., continued for two hours.

Of Koch and Wolffhügel.

Koch and Wolffhügel, in their experiments with dry heat, found that of a variety of materials exposed for three hours to a temperature of 295°, the majority had sustained marked damage. Black cloth, jute, and horsehair, however, were little or not at all injured.

Of writer.

The following table shows the results of some experiments made by me with different materials. In the experiments with dry heat, the breaking strain was not tested until after the lapse of a day or more, so that the materials had had time to regain their hygroscopic moisture, a point to be mentioned a little later on. As it appeared possible that the heat or moisture might affect the threads of the warp and woof differently, experiments in the case of flannel were made with strips torn lengthwise, as well as with others torn across the breadth of the piece.

It will be seen that the colour and tenacity of white flannel were affected by even a moderate exposure to heat; blankets also were deteriorated in a minor degree. Cotton, black cloth, and silk, white and coloured, were little affected by temperatures under 300°, though the tensile strength, especially of cotton, was somewhat impaired. The behaviour of leather is curious: it will bear a moderate application of dry heat, but is utterly disorganised by a very short exposure to steam, being shrivelled and converted into a gelatinous texture, which becomes very hard when dry.

Material.	Exposed to	Time.	Shrinkage. Per cent.	Tensile Strength before and after.	Colour.
White flannel, length	Steam 264°	½ hour	6·	100 : 88	Distinct yellow tinge.
Ditto breadth	Ditto	Ditto	5·7	100 : 88	
Ditto length	Ditto 225°	Ditto	5·4	100 : 97	Yellowish tinge.
Ditto breadth	Ditto	Ditto	4·1	100 : 96	
Ditto length	Ditto 212°	Ditto	5·8	100 : 92	Slight yellowish tinge.
Ditto breadth	Ditto	Ditto	6·0	100 : 100	
Ditto length	Dry heat 220°	4 hours	1·6	100 : 107	Yellowish tinge.
Ditto breadth	Ditto	Ditto	0·8	100 : 98	
Ditto length	Dry heat 280°	2 hours	2·0	100 : 100	Yellow tinge; dark in places.
Ditto breadth	Ditto	Ditto	0·4	100 : 95	
Ditto length	Simple washing	—	6·6	100 : 132	Very slight change.
Ditto breadth	Ditto	—	7·4	100 : 102	
Ditto length	Boiling water	½ hour	8·4	100 : 85	Dirty yellowish tinge.
Ditto breadth	Ditto	Ditto	6·9	100 : 95	
Tape (cotton)	Steam 260°	4 hours	?	100 : 82	Little alteration.
Ditto	Ditto 251°	½ hour	1·4	100 : 80	
Ditto	Ditto 212°	½ hour	2·	100 : 77	
Ditto	Dry heat 230°	4 hours	0·35	100 : 73	No discolouration; lost glaze.
Ditto	Ditto 280°	2 hours	0·7	100 : 73	Slightly darkened.
Ditto	Boiling water	½ hour	2·7	100 : 73	Lost glaze.
*Black cloth	Steam 251°	½ hour	0·9	100 : 100	No alteration.
Ditto	Ditto 212°	½ hour	0·	100 : 90	Slightly discoloured.
Ditto	Dry heat 230°	4 hours	0·	100 : 100	Slightly rusty, as if from long wear.
Ditto	Ditto 280°	2 hours	0·8	100 : 100	Ditto; more marked.
Ditto	Boiling water	½ hour	0·	100 : 100	Discoloured; dye having run.
White silk ribbon	Steam 251°	½ hour	2·1	100 : 100	No alteration.
Ditto	Ditto 212°	½ hour	2·0	100 : 100	No alteration.
Ditto	Dry heat 230°	4 hours	0·7	100 : 87	No change in colour; less glossy.
Ditto	Ditto 280°	2 hours	0·35	100 : 60	Brownish tinge; scorched.
Ditto	Boiling water	½ hour	1·	100 : 100	Lost glaze.

* This sample of cloth had apparently been already shrunk.

Articles.	Exposed to	Time.	Results.
Kid glove - - -	Steam 250° - -	½ hour -	Shrivelled up and converted into a gelatinous substance, very hard when dry.
Ditto - - -	Ditto 212° - -	5 minutes -	Ditto ditto
Ditto - - -	Dry heat 212° - -	1 hour -	Unaltered.
A felt hat - - -	Steam 228° - -	5 minutes -	Greatly distorted by softening of felt, and disorganization and shrivelling of leather lining.
Ditto - - -	Dry heat above 250° -	1 hour -	Unaltered.
Feathers - - -	Steam 260° - -	4 hours -	Yellowish and brittle.
Blankets - - -	Steam 251° - -	½ hour -	Yellow tinge.
Ditto - - -	Dry heat 240-268° - -	2½ hours -	Ditto puckered, somewhat hard and threadbare.
Dyed silk ribbon, various colours - -	Dry heat 230° - -	4 hours -	Unaltered.
	Steam 251° - -	½ hour -	Ditto.

It is to be noted that scorching is especially apt to take place where the heat is in the form of *radiant* heat. In one of the experiments with different forms of apparatus, it was found that the ticking of a pillow was uninjured, although exposed to a heat of 276° F., as tested by a thermometer laid beside it; in this case the pillow being screened from the direct access of heat rays from the source of heat; whereas in other instances in which the pillow was laid on wooden bars directly over the heated bottom of the chamber, it showed distinct stripes of scorching corresponding to the interspaces between the bars, although a thermometer laid beside it did not record a temperature any higher than, or even so high as, in the former case.

Scorching is brought about by radiant heat in two ways: First, textile articles, especially wool, are good radiators, as we may see by the copious deposit of dew or hoar-frost which takes place upon them when exposed in the open air on a clear night, and therefore with converse facility they absorb the rays of heat and are thus heated to a higher degree than the surrounding air. Secondly, in a chamber heated primarily by radiation the walls of the chamber and solid objects in its interior such as shelves, bars, and hooks, become by absorption of heat-rays hotter than the air, and consequently organic substances, such as articles of dress, are liable to be burnt where they may chance to come in contact with hot metal. On the other hand, if the chamber be heated by hot air warmed before its entrance, as in Ransom's stove, the walls of the chamber are no hotter than the air, and objects may come into contact with them without injury.

Overdrying.

2. Overdrying, short of actual scorching, renders many organic substances brittle; it is by this means that in pharmacy tough vegetable drugs, as roots, barks, &c., are prepared for grinding into powder. On the other hand, on exposure to moist air this brittleness is again lost; we know how the crispness of a newly baked biscuit is soon lost unless kept in a well-closed canister.

It was found by Dr. Henry in his experiments that the tensile strength of textile materials was weakened by exposure to dry heat, but was in great measure regained if the materials were allowed to remain in the air a day or two before testing.

M. Vallin (Traité des Désinfectants, p. 432) took hair and wool which had been previously well beaten, and exposed them for four hours to a temperature of 248° F. Portions again beaten immediately after being taken out of the stove yielded a layer of detritus, while other portions beaten only after a lapse of 24 or 48 hours, when they had had time to

regain their hygroscopic moisture, did not yield more waste than did unheated portions of the original material.

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It is evident that injury from overdrying can easily be avoided by allowing materials which have been subjected to dry heat to remain in the air long enough to recover their natural degree of moisture before manipulating them.

Fixing of stains.

3. An exposure to a heat of 212°, whether in the form of dry heat, of boiling water, or of steam, has the effect of fixing many organic colouring matters in animal and vegetable fibres, so that they cannot be removed by subsequent washing; in fact high-pressure steam is used by dyers and calico printers in an apparatus called a keir, for the very purpose of fixing their colours. This fixing of stains is especially marked in the case of albuminous materials coagulable by heat, such as blood. It is well known that in order to remove blood stains the cloth or garment must be steeped in cold water.

The following experiments were made by me on this point with the aid of Mr. J. W. Lyon, junr. Pieces of linen sheeting marked distinctively were steeped at one end in fresh sheep's blood, in dirty animal grease, and in claret; strips of calico were also steeped in ox-gall and in urine, and after exposure to heat the strips were washed in Messrs. Lyon's establishment in the ordinary manner, in boiling water with soap and soda.

The results are given in the following table :—

Treatment before Washing.	Results after Treatment and subsequent Washing with Soap and Soda.				
	Blood.	Dirty Grease.	Claret.	Ox-Gall.	Urine.
None - -	- - -	No stain -	Brownish stain	No stain -	No stain.
Soaked in cold water.	No stain -	—	—	—	—
Boiled in water ½ hour.	Blackish stiffened stain.	No stain -	Hardly any stain.	No stain -	No stain.
Steam 212° ½ hour	Do. do. rather darker.	Hardly any stain.	Brownish stain as above.	Yellow stain	No stain.
Ditto 260° ½ hour	Dark brown stiff stain.	Very slight stain.	Reddish stain, darker.	Yellow stain	Faint brownish stain.
Dry heat 240° 4 hours.	Ditto -	Hardly any stain.	Brownish stain, darker than first.	No stain -	Brown stain, like scorching.

This property of heat is an inconvenient one from our present point of view, and seriously limits the field for practical usefulness of disinfection by heat. It is very desirable that linen articles, sheeting, body linen, &c., which have been in contact with infection, should be disinfected before coming into the laundry, since otherwise they may infect the washerwomen, and possibly the linen of other households. Such objects, however, if soiled with blood, fæcal matter, &c., cannot be disinfected by heat, not even by boiling water, without indelibly fixing the stains. The only alternatives, therefore, are to put up with damage to this extent, to allow the articles to pass through the earlier processes of the laundry in an undisinfected state, or to attempt their disinfection by chemical means, which are uncertain and unsatisfactory. When the grosser dirt has been removed by soaking and rubbing in cold or tepid water the articles may be boiled without injury, and are then, doubtless, effectually disinfected.

Fusible and inflammable substances should be removed.

4. Injury may in some instances be caused by the melting of wax and such like fusible materials in ornaments or contained in the pockets of garments. At Nottingham articles have occasionally caught fire,

when the heat of the apparatus has not exceeded the normal degree, doubtless owing to lucifer matches being left in the pockets. To avoid such accidents the pockets are examined before the garments are placed in the stove, and if these be found to have holes in them, the linings are also examined.

It is sometimes necessary to disinfect articles of furniture with stuffed seats such as chairs and sofas. If the heat be too intense the varnished woodwork will blister, and in steam the glue with which veneers are put on may become loose.

Effect on colours.

5. Dry heat, short of actual scorching, does not often affect the colours of dyed goods. If not properly fixed, or in technical language "fast," steam or boiling water will cause them to run.

The surface gloss or "finish" of new goods is apt to be affected by heat, rendering the article in appearance like one that has been washed, but as articles requiring disinfection are not new, this is of little consequence.

Dr. Ransom speaks of one kind of white silk which easily turns brown by heat. Perhaps this may be due to the presence of sugar, which is sometimes used for loading silks, and when heated to a certain point becomes converted into a dark brown substance, caramel.

Shrinkage,

6. Dry heat causes little shrinkage in woven materials. Moist heat, on the other hand, or even wetting without much heat, causes permanent shrinkage, more especially in the case of woollen goods, as cloth, flannel, and blankets. The cloth of which men's clothes are made is (or should be) shrunk before they are made up: this shrinking is effected by exposing the cloth to steam. It will be seen, however, from the preceding table that the amount of shrinkage of flannel was quite as great after simple washing as after exposure to steam. A piece of washed flannel 50 inches long (measured after washing) only shrunk $\frac{1}{4}$ inch further, or $\frac{1}{2}$ per cent., on exposure for half an hour to steam at 228°.

and felting.

A more serious drawback is the felting together and loss of elasticity and fluffiness, upon which the warmth and softness of woollen materials depends. This elasticity depends upon the presence of the natural grease of the wool. M. Leblanc (quoted by Vallin) states that this grease (suint), which is a product of the perspiration of the sheep, is a mixture of mineral salts and organic compounds: in unwashed wool it amounts to nearly 50 per cent. of the total weight of the wool, and even in wool as washed never falls below 15 per cent. This grease is of a nature highly putrescible under the combined influence of warmth and heat; so that the quantity of it contained in a mattress, together with the contaminating infiltrations from human bodies, and the excrements of moth larvæ (amounting in bedding often to 1 per cent. in weight of the whole), form collectively a very large mass of decomposing matter, which must largely add to the contamination of the air of inhabited dwellings. On the other hand, if the wool be too well cleaned, so as entirely to remove the natural grease, it loses its strength, suppleness, and elasticity, the qualities for which it is especially valued. The suint is soluble in boiling water; water in which wool has been boiled for an hour is charged with an extremely fœtid matter, rich in products containing sulphur; and after this treatment the wool resembles cotton, it easily felts together, and has permanently lost its elasticity.

These observations explain how it is that blankets will not bear boiling in water; by the removal of the grease and felting together of the wool they lose their softness and warmth and become hard and threadbare. They may be washed in cold water or exposed to dry heat or

steam of moderate temperature without much deterioration, but a frequent repetition of these processes brings about in time a change similar to that effected by boiling water. Moreover, if wool be piled closely together when hot, the hairs, through the softening of the coatings of grease surrounding them, become glued together so that when cold the wool is felted into masses.

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7. Wetting is undesirable in the case of some kinds of goods as producing shrinkage and causing colours to run, as well as involving the labour of subsequent drying.

Wetting.

We need only consider the question of the degree of wetting in connection with steam.

When a cool body, such as a pillow, is placed in an atmosphere of steam, some of the steam will be condensed upon it, and if the relative volume of the steam be sufficient the temperature of the cool body will be raised to 212° F., and this temperature having been attained, no further condensation of steam into water will take place. Owing, however, to the high specific and latent heat of steam the weight of steam thus condensed will be much less than the weight of the body heated to 212° F. by its condensation.

In the experiments with Benham's apparatus, in which the steam is not superheated, the increase of weight in a pillow exposed to the action of the steam was found in two experiments to be 13 and 14 per cent. respectively of the previous weight of the pillows. On the other hand, when one of the pillows was placed under a tap and saturated with cold water, it was found to have increased in weight 140 per cent. The amount of water derived from the condensed steam was therefore only a tenth of the quantity which the pillow would hold when saturated. A roll of flannel in the same machine increased in weight 22 per cent., a coat 36 per cent. The amount of moisture absorbed depends not only upon the nature of the materials, but upon their previous state of dryness or dampness; if wet, extra heat would be required to raise them to the temperature of the steam, and more steam would thereby be condensed.

In Lyon's apparatus, in which the steam is used at a higher temperature, being superheated by the higher degree of heat corresponding to the extra pressure on the outer case, the amount of wetting is less; in experiments with bales of rags the increase of weight varied from 3½ to 5 per cent., the greater part of which was again lost on a few hours exposure to the air.

V.—*On the Practical Utility of Disinfection by Heat.*

The limits of the field of practical usefulness of disinfection by heat may be gathered from what has gone before.

For washable articles which will stand boiling in water, no other procedure is necessary. It is even maintained by Dr. Russell, in the paper already quoted, that a thorough ordinary washing constitutes a perfectly efficient disinfection, on the ground that the infective matters retained by a textile fabric probably exist in the form of dirt adhering to the surface of the fibres, and not permeating their substance. (It is of course premised that the washed articles are not re-infected by being allowed to mingle with unwashed ones, or to remain after washing in an infected atmosphere.)

The difficulty is that, granting that linen may be disinfected by washing, if conveyed in undisinfected state to the wash, it may communicate infection to the washerwoman and to the linen of other households; such transmission would probably also be an offence against section 126 of the Public Health Act, 1875. By previous boiling the linen might be

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disinfected, but if soiled this might injure it by fixing stains. The best plan is to place the linen on being left off, and before it is removed from the infected precincts, to steep in a pan of cold water, which may contain some chemical disinfectant, though it is doubtful if much additional security be gained thereby, unless the solution be a very strong one, in which case it may cause injury to the clothing. After the grosser impurities have been removed by this preliminary rinsing, the clothes may be boiled without damage, and (with care to avoid re-infection) may be considered free from infection and sent away, if necessary, to undergo any further processes of the laundry which may be required.

Some such proceeding as this is commonly carried out under the advice of the medical attendant when infectious disease invades households of the better class.

The articles for which a more technical "disinfection" by heat is especially required are such as will not bear washing in boiling water, such as blankets, rugs, carpets, and cloth clothes generally, pillows, beds and mattresses, furs, and dresses. Articles of furniture with stuffed seats and backs, as chairs and sofas, may require disinfection by heat if they have been in an infected room, and such articles are often so exposed to heat in order to check the ravages of moths. Again, exposure to heat is often employed in workhouses and similar establishments to destroy lice in clothing, or the animal and vegetable parasites which cause certain skin diseases. It may be necessary to insist on the disinfection of rags coming from places where epidemic diseases prevail, and in such cases heat, especially in the form of steam, affords the most satisfactory means. Letters sent by patients suffering from infectious diseases, or coming from countries in which epidemics prevailed, might readily be disinfected by heat, provided that they were not fastened with sealing-wax. Books which have been used by the sick or convalescents may be disinfected by heat, but the effect of steam on leather bindings must be remembered. In some hospitals the periodical heating of pillows and mattresses is practised as a part of the ordinary routine of antiseptic practice.

For some of these purposes dry heat and steam are both applicable, provided that in the case of steam precautions are taken to avoid undue wetting. Steam possesses the advantage over dry heat of requiring far less time and a lower temperature for penetration into bulky objects, and for destroying contagia; it is on these grounds especially adapted for the purification of bedding, bales of rags, large bundles of clothing, and other objects difficult of penetration. On the other hand, it instantly destroys leather articles, so that these must be disinfected, if necessary, by careful exposure to dry heat. This, however, where steam is employed, need not involve the erection of a separate apparatus, for a steam-chamber provided with an outer steam-jacket, as those described later on in this report, may be converted into one for dry heat merely by letting steam into the casing, and not into the interior.

The moistening of the atmosphere of a hot-air chamber by steam from an evaporating dish of sufficient size, or from a separate boiler, appears to have a distinct advantage in increasing the penetrative power of the heat, though it would appear from the experiments previously recorded the superior germ-destroying power of steam is not thereby attained.

VI.—On the different Forms of Apparatus for Disinfection by Heat.

A.—General Considerations.

Requisites a good apparatus

The characters of a good disinfection chamber are as follows:—

1. A uniform distribution of heat in all parts of the chamber.

2. The maintenance of the heat with constancy at any required degree. On Disinfection by Heat; by Dr. Parsons.

3. A trustworthy index to the actual temperature of the interior at the time being.

After these in importance come:—

4. Rapidity of action both in the first getting up of heat and in effecting disinfection.

5. Economy of first cost, and of working.

The uniformity and equable distribution of the heat are of essential importance, as it is only under these conditions that we can, on the one hand, avoid injury to the articles to be disinfected, and, on the other hand, ensure their due exposure to the requisite degree of heat. If one part of the chamber be to any considerable degree hotter than another, articles placed in the hotter part may be scorched before those in the cooler part have been sufficiently heated.

Again as the penetration of dry heat into bulky articles is a slow process, it is necessary for thorough disinfection that such articles should remain in the oven for several hours, during which time the temperature should be kept as nearly as possible constant, or, as before, we have, on the one hand, the risk of scorching, on the other, the danger that the objects may not be thoroughly disinfected.

In order to ensure security in both these respects, it is necessary that the attendant should be able to ascertain at any instant what is the actual temperature of the interior of the chamber.

It is only with stoves on the dry-heat principle that difficulties in these respects are met with; but in these they are very great. In a steam chamber the temperature is almost uniform, and remains so as long as the pressure of steam is kept constant, and the pressure gauge is at any moment a sure guide to the temperature.*

1. Even in chambers heated by steam the temperature is not absolutely uniform. In Benham's, in which the pressure of steam on the outer casing and chamber was alike, only 2° difference was found in different parts, but in Lyon's, in which a higher pressure of steam in the case is used, there was a difference of 8° in different parts, the temperature being lowest next the door, which is not steam jacketed, and on which side, therefore, there is a loss instead of an access of heat. Uniform distribution.

In dry-heat chambers the variation of temperature in different parts was, as a rule, much greater. In Ransom's stove when thoroughly warm it was only 9°, but in two or three kinds it was nearly 100°, and in the others it ranged between these two limits. As a rule the temperature is more unequally distributed in chambers in which the heat is applied to the walls at the bottom or sides than in those in which the products of combustion pass directly into the chamber, and in apparatus of the latter kind it is more uniform in proportion as the source of heat is removed farther from the part of the chamber in which articles to be disinfected are placed. In other words, the temperature is more uniform in proportion as the chamber is heated by hot air, and not by radiation. There are further these differences between the distribution of heat in the two cases: that in chambers heated by radiation the hottest part is that nearest to the heated side (usually the bottom), while in those heated by hot air, it is at the top; that in chambers heated by radiation the walls, &c., are hotter than the contained air, whereas in those heated by hot air they are of the same temperature, or

* If the pressure of steam in the outer jacket be greater than that of the steam in the chamber, the latter will be superheated above the temperature corresponding to its own pressure.

On Disinfection by Heat; by Dr. Parsons.

cooler; and that in chambers heated by radiation objects in a direct line with the source of heat receive more heat than those screened from a direct view of it.

And constancy of heat.

2. The facility with which uniformity of temperature can be secured during the time necessary for disinfection depends upon the nature of the fuel.

With steam it is only requisite to keep up the pressure to the degree corresponding to the temperature required, and set the safety-valve so as to blow off the excess if that pressure should be exceeded.

In a dry-heat chamber heated by gas it is comparatively easy to keep the temperature uniform, since so long as the pressure of gas remains the same, the amount of heat generated in a given time keeps constant. Thus in a chamber heated by gas the temperature will rise, rapidly at first, then more slowly, until it reaches a point at which the loss of heat exactly balances the amount generated by the combustion of the gas, and having attained this point it will then remain constant as long as the pressure of gas and other conditions remain unaltered. Consequently, it is only necessary, when the required temperature has been attained, to diminish, by the turning of a cock, the current of gas to such an extent as will suffice to maintain the temperature at that point, and when this has been done, but little superintendence is required to guard against variations due to fluctuations of gas pressure, effects of winds upon the current of air through the apparatus, &c. In the best forms of apparatus, as Ransom's and Scott's, moreover, even these variations are guarded against by the use of an automatic thermo-regulator, which, when the temperature rises above the point at which it is set to work, diminishes the supply of gas; when it falls, increases it. To facilitate the getting up of the heat, a by-pass is provided to allow an ample supply of gas at first. When the required degree of heat has been attained, this is closed, and the regulator maintains the temperature constant at the degree at which it is set. Variations in pressure of gas may further be guarded against by the use of a gas-governor. Two other contrivances to guard against an undue elevation of temperature may also be mentioned: 1st. A chain with a link of fusible metal, which, melting when the temperature of the chamber attains a certain point, allows a weight to fall, shutting off the supply of gas (Ransom's and Scott's apparatus); and 2nd. An automatic ventilator, opened by the elongation of a copper rod when the chamber is hot (Scott's).

For use in establishments such as hospitals gas as fuel has the further advantage of ease and cleanliness of manipulation, so that it can be attended to by a nurse.

It is quite otherwise with solid fuel, as coal or coke. A furnace heated with solid fuel can only be kept at an approximately uniform temperature by the constant attention of an experienced stoker. The generation of heat is not uniform as in the case of gas, but on the contrary, as the fuel becomes fully ignited, the fire gets hotter and hotter; by and bye, on the other hand, as the fuel is burnt away, the fire gets low and gives less heat. If now the door be opened and fresh fuel put on, the temperature of the furnace, instead of being raised, is at first still further lowered, until the fresh fuel has been thoroughly ignited. On the other hand, if the temperature rises too high it cannot be readily or quickly lowered. Nor is it easy to adapt means of automatic heat regulation to a furnace heated by solid fuel; the only contrivance of the kind of which I am aware being the automatic ventilator provided to Scott's apparatus, when constructed to burn coal. Possibly it might be found practicable to place in the chimney of such

stoves a damper closing automatically as the temperature of the chamber rose. In stoves heated directly by coal or coke the products of combustion cannot be admitted into the chamber, consequently in such stoves the heat is applied to the floor or walls, and the chamber is warmed by radiation therefrom; a mode of heating the disadvantages of which I have already pointed out. Of course for portable machines, or in places where gas is not available, the use of solid fuel is a necessity.

On Disinfection by Heat: by Dr. Parsons.

And trustworthy indicator of degree of heat.

3. To find a means of reading at any moment the actual temperature in the interior of a hot-air chamber is a problem which the inventors of disinfecting apparatus have endeavoured to solve in several different ways, but in most cases with very indifferent success. In Dr. Ransom's stove the mean between the readings of the inlet and outlet thermometers approximates to the mean temperature of the interior of the chamber, and in one example of Bradford's apparatus the readings of the fixed thermometer did not differ materially from the mean temperature of the chamber, but in all the other forms of apparatus tested by me the readings of the thermometer pertaining to the apparatus fell far short—in some instances by as much as 100°—of the temperature recorded by registering thermometers placed in the hotter parts of the interior. This want of correspondence is due to two causes: first, to the thermometer, in order to allow it to be read, being placed close to the walls and not in the hottest part of the chamber; and second, to its being needful, in order to protect it from injury, to enclose the bulb of the thermometer in a metal tube, by which it is in considerable measure screened from the access of heat, for as this tube passes through the walls of the chamber, the heat which it receives is in part conducted through the wall to the outer air and there dissipated.

In several forms of apparatus the thermometer scale is fixed on the outside of the chamber; the stem is bent and passes through the wall, and the bulb, enclosed in a perforated metal tube, projects a few inches into the interior. In Leoni's apparatus a pyrometer is in some cases employed, being similarly placed. In Dr. Langstaff's and Taylor's hot-air chambers, and also sometimes in that of Messrs. Fraser, the thermometer is placed on the inside of the chamber opposite a pane of glass through which it can be read, but as the pane of glass allows a greater loss of heat to take place through it than other portions of the chamber walls do, the thermometer in this position does not mark the full degree of heat. In Fraser's apparatus another device is adopted; a long straight thermometer is enclosed in a brass tube, perforated opposite the bulb, and having a longitudinal slit through which the mercury can be read. At the end farthest from the bulb this tube is fastened to a wooden handle, which fits into a conical hole in the door of the chamber in such a manner that the thermometer projects horizontally about 2 feet into the chamber, and can be withdrawn for reading. It will be seen from the account of Fraser's apparatus that the thermometer thus placed does not give an exact indication of the heat of the interior, and it is more troublesome to read than a fixed thermometer.

The means of indicating the temperature of the chamber to which I have been led to give the preference, when an arrangement of thermometers such as that in Ransom's stove cannot be adopted, is a pyrometer actuated by the expansion of a long metal bar which projects across the interior of the chamber. Such a bar being less fragile than the bulb of a thermometer, need not be enclosed in a case, but may be exposed directly to the heat, and its length enables it to tell the temperature existing through a space of several feet, not, like a thermometer, only that in the immediate neighbourhood of the bulb. In the ex-

periments with Bradford's apparatus at Leamington and Salford such a pyrometer was found to indicate correctly the temperature of the chamber, though in Leoni's apparatus the pyrometer failed to do so equally with the thermometer. I am not acquainted with the construction of the pyrometer in this instance. I am informed, however, that the objection to pyrometers is that after being in use for some time the rate of expansion of the metal bar is apt to become altered, so that it ceases to be read correctly ; this one would suppose might be remedied by re-adjusting the instrument.

If a thermometer be used with a stem passing through the wall of the chamber, the metal tube in which the bulb is enclosed for protection should not pass through the wall, but should be fixed to the inner surface, and the scale to the outer surface, the space between around the thermometer tube being filled with asbestos or other non-conducting material. A wirework guard might, perhaps, with advantage be substituted for a tube of solid metal.

In any case before a disinfecting apparatus is used, a careful trial should be made with registering thermometers placed in different parts of the chamber ; the readings of these should be compared with those of the fixed thermometer or pyrometer. If it be found that the indicated and actual temperatures do not correspond, the fact should be frankly recognized and a statement should be furnished by the makers, showing what internal temperature a given reading of the fixed thermometer indicates.

Thus Messrs. Nelson and Sons, in the instructions for the use of their apparatus, state that a temperature of 140°, as shown by the fixed thermometer, corresponds to one of 200° in the chamber, and recommend that the thermometer should never be allowed to exceed 180°.

Rapidity of action.

4. The rapidity with which an apparatus can be raised to the degree of heat necessary for disinfection varies according to the nature of the fuel used, the proportion between the supply of heat and the space to be heated, the directness of application of the heat, the construction of the chamber, and other circumstances. In the same apparatus it differs at different times according to the temperature of the surrounding air, and the initial temperature of the apparatus itself, the dryness or dampness of the walls of the chamber, the force and direction of the wind, the supply of gas, and other circumstances. In chambers heated by coal it takes longer, as a rule, than in those heated by gas. Dr. Ransom's apparatus, however, which is heated by gas, is very slow in getting up heat. Steam chambers are heated in a few minutes if there be a supply of steam at hand ; but to get up steam specially would, of course, occupy a much longer time.

Although there is a decided advantage in being able to bring an apparatus to the required degree of heat in a short time, yet it is attended, except in the case of steam chambers, with the correlative disadvantage that unless care be exercised, there is the greater risk of the limits of safety being exceeded.

As regards the time necessary for the disinfection of objects when the chamber has been heated to the desired degree, my experiments have not been sufficiently numerous, nor made under conditions sufficiently uniform, to enable me to form an opinion whether, with equal degrees of temperature, penetration of heat takes place more rapidly in one form of dry-heat chamber than in another, though they prove that the length of exposure recommended in the directions issued by the makers is often quite insufficient to heat such objects as pillows throughout their whole thickness. In Bradford's and Taylor's machines, in which the air is moistened by the evaporation from a large pan of

water or by the introduction of a jet of steam, the time required for penetration of heat appeared to be shortened, and this is what might be expected, on theoretical grounds. On Disinfection by Heat; by Dr. Parsons.

In a steam chamber, however, penetration of heat takes place very much more rapidly, so that disinfection can be accomplished in a very small fraction of the time necessary to perform it with safety in the dry way. This is in practice of great advantage, especially where large quantities of materials, or bulky objects, have to be dealt with. One steam chamber will accomplish in a day many times the amount of work which can be got through by a hot-air chamber of equal capacity. There is the further advantage that the articles to be disinfected can be speedily returned to their owners—a matter of importance in some cases, as to poor people who have only one bed.

5. It is beyond the purposes of this report to compare the relative economy in first cost and in subsequent working of the different forms of apparatus described—a subject to which authorities about to choose one may be trusted to give due consideration. It need hardly be said that the prime cost of the best forms of apparatus may be expected to be more than that of contrivances of less perfect character. Economy of first cost.

In large districts and large establishments the most efficient apparatus will be the cheapest in the end, although it may cost somewhat more to start with; in small districts and small establishments where a disinfecting apparatus would only occasionally be required to be used, the question of prime cost will be of greater weight. Where the articles likely to require disinfection are of comparatively small value, as in pauper institutions, and the risk of occasional damage is, therefore, not of so much consequence, a cheaper form of apparatus may suffice; whereas at a municipal disinfecting station, to which articles belonging to all classes of the community may be brought, it would be false economy, for the sake of a saving of, say, 100*l.* in first cost, to run the risk of destroying valuable property and exciting an amount of opposition which would mar the usefulness of the whole establishment. Moreover, as I have pointed out before, if disinfection can be effectually carried out only at the risk of injury to the articles submitted to it, it is liable to degenerate into a mere form, of little use as a safeguard against the spread of disease.

I have not any statistics of the relative cost of working of the different kinds of apparatus; but of the expenses of maintaining a disinfecting station, the chief part are such as would be incurred equally, whatever apparatus were used. So far as I can learn there is no great economy in heating a hot-air chamber by coal rather than by gas; a shilling's worth of coal or coke gives out more heat than a shilling's worth of gas, but the heat yielded by the gas is more completely utilised, and less attendance is required. At the Hampshire Nurses Institute, the cost of fuel is under 1*s.* 6*d.* each time of heating, but it is necessary to employ a stoker specially each time that the apparatus is used. In the apparatus heated by gas the consumption of gas varies from 60 to 200 cubic feet per hour, costing, at 3*s.* 6*d.* per 1,000 cubic feet, from 2½*d.* to 8*d.* per hour,—a larger consumption being required for first getting up the heat than for maintaining it when once attained. The employment of a self-acting gas regulator effects a saving in attendance, as with its aid the stove when charged and set to the proper degree may be left unwatched during the night or as long as is necessary to effect disinfection. Vallin indeed goes so far as to say: "We do not hesitate to say that it is "necessary absolutely to reject every stove which is not furnished with "one of these contrivances" (loc. cit., p. 435). And of working.

On Disinfection by Heat; by Dr. Parsons.

Other points.

The following are other points to be mentioned in connexion with different forms of disinfecting apparatus.

Ventilation.

It is necessary to provide openings for the ventilation of the chamber. Where the products of combustion pass into the chamber itself, it is absolutely necessary that there should be a supply of fresh air in the place of that consumed, and an exit for the products of combustion, or the gas flames would be extinguished. The ventilation of the chamber further serves to remove vapour and effluvia, and can be used as a means to reduce the temperature if excessive.

The vapours given off from heated clothing, &c., especially if dirty, are very offensive, and it is possible that those given off in the early stages of the process may contain particles not deprived of their infectious properties. It is therefore desirable that these vapours should be dealt with in some way so as to prevent noxious effects. Where coal is burnt the outlet should be carried into the chimney, or, better still, as in Fraser's stove, into the hearth of the furnace; in gas stoves one or more burners may be placed in the outlet flue. In Leoni's apparatus at Limehouse the outlet flue is provided with a condenser charged with quicklime and tow saturated with carbolic acid, but the effect of this did not seem to be great, as the air which had passed through it was found to extinguish a lighted match.

Use of chemicals as adjuncts to heat.

In some forms of apparatus provision is made for the use of chemical agents, as sulphur and carbolic acid, as an adjunct to disinfection by heat. In view, however, of the proved efficacy of heat as a disinfectant, and the doubtful efficacy of most chemical disinfectants, this seems, as a rule, unnecessary. It is to be remembered, however, that, as mentioned in an early part of this report, Koch has found that the disinfecting effect of certain vapours is aided by heat, so that a contagium may be destroyed by a chemical vapour in a certain proportion, at a moderately elevated temperature, although neither the vapour nor the same temperature acting alone would have had any such effect. Possibly the employment of, *e.g.*, the fumes of burning sulphur may be useful in a badly designed chamber in which, owing to the unequal distribution of the heat, or its liability to variations, it is impossible to ensure that all the contents of the chamber have been submitted to an adequate degree of heat without at the same time running the risk of injuring those articles in the hotter parts.

Materials of walls.

The material of which the walls of a disinfecting chamber are made should be non-conducting, so as to prevent waste of heat, and assist its equable distribution. The larger chambers are often built of brick; smaller ones are commonly of iron, covered externally with wood, felt, slag-wool, or other non-conducting material. The double iron panels with an intervening layer of non-conducting material used in Dr. Scott's hot-air chamber answer the purpose very well, the outer surface remaining cold, except near through pieces, even after long use.

The walls of chambers in which high-pressure steam is used must be made of wrought iron or copper of adequate strength, and must be carefully tested to avoid risk of accident.

Transport of articles for disinfection.

Another question arises as to the means of safely transporting infected articles to the disinfector, and of bringing them back after disinfection without risk of their being re-infected by coming into contact with other infected things.

Some kinds of apparatus are made in a portable form, so that they can be moved about from place to place as required. Such machines

are convenient for use in temporary hospitals and camps. They have also been found of service by rural sanitary authorities for dealing with outbreaks of infectious disease occurring in outlying villages. In such a case it has seemed better to carry the apparatus to the place where it is wanted, rather than by bringing the clothes to a stationary apparatus to run the risk of conveying infection to a place previously uninfected.

On Disinfection by Heat; by Dr. Parsons.

In one of the machines of this class, invented by Dr. Heron Rogers, of Retford, the clothes to be disinfected are placed in a box provided with a sliding lid. This box is carried out and placed lid downwards over an aperture in the roof of the hot chamber, the lid is withdrawn, and the clothes fall out on to racks in the chamber.

In the larger forms of Fraser's apparatus an iron van is provided; this is sent to fetch the clothes, which are arranged in it on racks. It is then wheeled bodily into the chamber, where it is thrown open, and allowed to remain for the time considered necessary for disinfection; it is then withdrawn and the clothes, without removal from the van, are carried back to their owners. I have not made any trials with this arrangement, but should doubt whether there was not a danger, on the one hand, of the clothes in the van not being exposed to the full degree of heat, and on the other, of their being burnt where in contact with the hot iron. The van also must take up much room in the chamber.

In the most approved arrangement the chamber is furnished with a door at either end, which, for additional safety, may be made so that only one end can be open at a time. The building in which the stove is placed is divided by a partition wall into two unequal compartments, the larger being for infected, the smaller for disinfected articles. The stove is placed in this partition wall in such manner that one door opens into one compartment, and the other into the other. Thus the infected articles being taken into the chamber through one entrance, and after disinfection being removed by another, there is no risk of their again coming in contact with infection.

For the collection of the infected articles, and the redistribution of the disinfected ones, different vans or hand-carts should be used. For the sake of distinction these may conveniently be painted of different colours.

B.—*Classification of Apparatus.*

Classification of apparatus for disinfection.

Apparatus for disinfection by heat may be classified as follows* :—

(a) *By hot air*:—

1. Apparatus in which the heat is applied to the outside of the chamber, and the products of combustion do not enter the interior.

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* Another division might perhaps have been made, viz., of apparatus in which hot moist air is employed, this being again subdivided into those in which the air is moistened by evaporation from a vessel of water contained in the heated chamber, as Bradford's, and in some cases Scott's apparatus, or those in which steam from a separate boiler is led into the apparatus by a pipe, as in Taylor's and Schimmel's. I have not, however, adopted this classification for the following reasons: That the apparatus in which steam is used as an adjunct are also often used without it, so that the same apparatus would sometimes fall into one class, sometimes into another; that the proportion of steam used is in some cases so small as to have but a trifling effect in moistening the air of the chamber; and that the behaviour of hot moist air upon micro-organisms resembles that of dry air rather than that of steam.

Or. Disinfection by Heat; by Dr. Parsons.

2. Apparatus in which the heated products of combustion enter the interior.

3. Apparatus heated by steam or hot water circulating in closed pipes.

4. Apparatus in which air previously heated is blown into the chamber.

(b) *By steam:*—

5. By a current of free steam.

6. By steam confined in a chamber at pressures above that of the atmosphere.

(a) By hot air. By heat applied to walls from outside.

1. The apparatus here described coming in the first class are Nelson's, Fraser's, Dr. Heron Rogers', Dr. Longstaff's, Taylor's, and Bradford's.*

Apparatus of this kind have, as a rule, the disadvantage that the heat being largely in the radiant form is very unequally distributed through the interior.

By heated products of combustion traversing chamber.

2. This principle, viz., that of allowing the air heated by contact with the flame and mingled with the products of combustion (these, in the case of ordinary gas, being watery vapour, carbonic acid, and a small proportion of sulphurous acid) to enter the chamber, can only be employed in apparatus heated by gas, but is adopted in most of these, as in the Nottingham stove (Dr. Ransom's), Dr. Scott's (when heated by gas), Leoni's, Jennings's, and that at the Hôpital St. Antoine, Paris. In the first and last-mentioned stoves the gas is burnt in a separate compartment at the side, the hot air alone, and not rays of heat, entering the chamber. In the others the gas burners are placed in or under the chamber itself, so that the chamber is heated by radiation as well as by hot air. In Dr. Scott's stove the burners are luminous, in the other British apparatus on this principle they are atmospheric.

The difference from the present point of view between a luminous and an atmospheric flame is that the latter, consisting only of heated gases, gives off little radiant heat as compared with a luminous flame, which contains highly heated solid particles of carbon. This may be shown by holding a common Bunsen burner about a foot from the face and on the same level, and stopping up the air-holes with the finger and thumb; when the flame is thus rendered luminous a distinct increase in the amount of heat received from it by the face is perceived. The disadvantage of an atmospheric flame is that if turned low it is liable to "catch back" or go out altogether.

By hot water or steam pipes.

3. Heating by coils of steam or hot-water pipes appears to be a principle more in favour on the Continent than in this country. At the Monsall Hospital, Manchester (Dr. Thorne's Report, pp. 173–74), there is a disinfecting chamber warmed by hot water circulating under pressure in closed pipes; it appears to answer well, with the exception of the trouble occasioned by leaky joints.

Abroad the principle is adopted in the apparatus of M. Herscher and that at the Hospital St. Louis, Paris (as represented in the International Health Exhibition of 1884 by a model and drawings), in the apparatus at the Moabit Hospital, Berlin, in which Dr. Koch's experiments with dry heat were made, in those of Dr. Esse, of Schimmel & Co., and others.

By hot blast.

4. The principle of heating the air to a given temperature by passing it through tubes over a large heated surface, and then forcing it into the chamber—in other words, of a hot blast—has been attempted, so far

* Also Dr. Scott's in the form heated by coal.

as I know, only by Mr. Seagrave, and cannot be said to have been as yet reduced to practice for disinfecting purposes. On Disinfection by Heat; by Dr. Parsons.

5. A current of steam at atmospheric pressure was found by Koch and Wolffhügel to be a very effective means of disinfection, and the experiments before described made for the purposes of this report have had the same result. I have not met with any apparatus constructed on this principle for the purpose of disinfection, though a jet of steam is employed in some trade processes of cleaning, as for the purifying of feathers. Probably the wetting produced by steam at atmospheric pressure militates against its employment, and has prevented its coming into use for disinfecting purposes; otherwise it might, one would think, be employed with advantage, as the apparatus used might be cheap and simple, no great strength being required, as for machines in which high pressure steam is used. Moreover, when steam escapes from under pressure into the air its temperature rapidly falls. Thus a thermometer held in a jet of steam from a boiler in which the pressure was 30 lbs., marked only 204° F. (b By steam. By a current of free steam.

6. For the employment for disinfection of steam under pressure two very similar machines exist, viz., those of Washington Lyon, and of Benham & Sons, both of which are very effective within the range of their respective capabilities. A steam apparatus is also made by Thos. Bradford & Co., of Salford. By steam under pressure.

C.—*Descriptions of and Experiments with the various forms of Apparatus in use.*

(a) *Hot-air apparatus :—*

1. Apparatus warmed by heat applied externally.

Nelson's Patent Disinfecting Apparatus.

(Makers, James Nelson & Sons, Leeds.)

Nelson's disinfecting apparatus.

This apparatus is extensively used in workhouses and other institutions throughout the country, being employed especially for the purpose of destroying vermin in clothing.

It consists of a rectangular iron chest, with double side walls. The smaller sizes have a hinged and counterpoised lid; the larger ones two doors opening in front. Underneath the bottom, which is of a single plate, is a series of luminous gas jets; the heated air from these plays upon the bottom, and passing up between the outer and inner walls, is carried off by a flue without entering the interior of the chamber. The chamber is furnished with two openings for ventilation, an inlet at the bottom and an outlet at the top at the opposite end communicating with the flue; these openings are furnished with slides by which they can be closed or opened.

There is a thermometer fixed near the outlet flue with the bulb in the space between the walls; this thermometer, however, does not profess to show directly the temperature attained within the chamber, but only to furnish an indication from which that temperature may be inferred.

According to the statement of the makers, a temperature of 140° as shown by the thermometer corresponds to one of 200° inside the chamber, and it is recommended that the apparatus should be worked at a temperature as shown by the thermometer of 140° to 150°, and that the thermometer should never be allowed to exceed 180°.

On Disinfection by Heat; by Dr. Parsons.

Experiments made at Croydon Workhouse.

The following experiment was made with a large-sized apparatus (7 feet long, 2 feet 6 inches deep, and 5 feet high), at the Croydon Union Workhouse.

The apparatus being cold, four registering thermometers were placed in different positions in the chamber, the doors were closed and the gas lighted.

In 10 minutes' time the fixed thermometer stood at 165° : the gas was then turned off. The thermometers in the chamber were found to read as follows :—

1.	On bars close to the bottom - - -	302° F.
2.	Close to the top, at end furthest from flue -	227° „
3.	„ „ at end next the flue -	220° „
4.	Suspended in centre of chamber - -	236° „

There was thus a difference of 82° between the highest temperatures attained in different parts of the apparatus.

The superintendent informed me that the apparatus was used at a temperature such that the fixed thermometer stands at 140° to 160°, the gas being turned off as soon as it reaches 160°. With this heat clothes are often scorched, but he considers it impossible to kill vermin in clothes effectually without scorching them.

At Ware Workhouse.

An experiment was also made with a smaller apparatus (measuring 6 feet long, 2 feet deep, and 3 feet high), in the Ware Union Workhouse. This had a lid opening at the top.

Four thermometers were placed in it in different positions, the fixed thermometers standing at 80°, and the gas was lighted. In 22 minutes the fixed thermometer had risen to 142°, when the gas was turned off. The temperatures registered by the thermometers were as follows :—

1.	On bars, close to the lid - - -	270°
2.	„ at mid height in the centre - -	268°
3.	„ „ at end next outlet -	259°
4.	On grating, near bottom - - -	287°

In this experiment the temperature in different parts of the chamber was found to be more uniform than in the one at Croydon, the difference between the highest and lowest readings being 28° instead of 82° ; but it was shown that the fixed thermometer is a very uncertain guide to the temperature of the interior, that at the bottom being 80° higher than by the indication of the fixed thermometer it should have been, according to the makers' statement.

At Aston Workhouse.

Better results were given by an apparatus at the Aston Union Workhouse measuring 7 feet × 3 feet and 3 feet high.

Five registering thermometers having been placed in it in different positions, they were taken out as soon as the fixed thermometer had attained 150°, and were found to read as below :—

1.	On top bars, centre - - - -	220° F.
2.	„ „ end next flue - - -	220° „
3.	On middle bars, centre - - - -	197° „
4.	„ „ end next flue - - -	224° „
5.	Suspended just above bottom, centre - -	221° „

In a second experiment a pair of fustian trowsers was laid out flat on the middle bars, a thermometer being placed between two folds. Four other thermometers were placed at the same time in different parts of the apparatus. The gas was turned up and the heat continued for 40 minutes (half an hour being the usual time of exposure for such articles), the fixed thermometer rising from 136° to 174°. At the end of that time the thermometers registered—

1. In middle of chamber	- - - -	220°
2. End next flue	- - - -	247°
3. End furthest from flue	- - - -	218°
4. Close to front	- - - -	220°
5. In trowsers	- - - -	155°

On Disinfection by Heat; by Dr. Parsons.

Thus the time commonly allowed is not sufficient for disinfection.

It was stated that in only one instance had any article been found scorched.

Advantages and disadvantages.

The advantages of this apparatus are its comparatively small first cost and the short time which is necessary to attain the required temperature.

Its disadvantages are the very unequal distribution of heat in the chamber, owing to the bottom and sides being heated by the flame, and the absence not only of any self-regulating contrivance, but also of any trustworthy guide to indicate the temperature actually attained in the interior. In consequence of these defects, it is not surprising to learn that complaints of articles being scorched are of not unfrequent occurrence, while, if with a view to avoid this accident the temperature be kept comparatively low, there is the opposite danger that the articles may not be exposed in every part to a temperature sufficiently high for disinfection.

The following experience at Salford is taken from Dr. Thorne's "Report on the Use and Influence of Hospitals for Infectious Diseases," p. 232:—

"This apparatus (Nelson's) has been abandoned, not only because a considerable number of articles were every now and again scorched and even destroyed in it, but because it was found impossible to subject clothes, &c., to any definite temperature in the apparatus, there being no constant relation between the temperature as indicated by the external thermometers, and that actually registered by an instrument placed inside the article to be disinfected. The temperature as indicated by the thermometer fixed in the stove when articles were scorched is stated never to have exceeded 180° F."

Similar experience is recorded in the same report from Darlington (p. 110), Goole (p. 124), Huddersfield (p. 134), Middlesbrough (p. 190), and Scarborough (p. 237), and in several of these places the use of the apparatus had, in consequence, been abandoned.

The Medical Officer of Health for Coventry writes:—"I found it " impossible to get a temperature sufficiently high in this chamber to " destroy infective material, without at the same time burning the " articles contained. In some instances I had conclusive proof that " scarlet fever was contracted from bedding and clothing which had " been exposed to the process of stoving in Nelson's machine."

Fraser's Patent Disinfecting Apparatus.

Fraser's patent disinfecting apparatus.

(Makers, W. J. Fraser & Co., Commercial Road East, London.)

This apparatus is in large use among sanitary authorities. From a report by Dr. G. Paddock Bate, Medical Officer of Health for the parish of St. Matthew, Bethnal Green, I learn that of 30 vestries in the Metropolitan District, who are provided with a disinfecting apparatus, 13 use that of Fraser & Co., though in some cases improved or modified.

The apparatus is very simple, consisting of a brick-built oven heated by a coke fire underneath.

The largest ovens for the use of sanitary authorities are made with a pair of doors at either end, the bottom of the oven being level with

On Disinfection by Heat; by Dr. Parsons.

the ground; the clothes to be disinfected are collected in an iron truck which is wheeled bodily into the oven at one end; the doors of the truck are opened, and it is left there while the articles are undergoing disinfection, and wheeled out with them at the other end. (*See* plans opposite.)

In a smaller form of the apparatus, suitable for hospitals, &c., there are doors at one end only, and the articles to be disinfected are placed on wooden racks or shelves.

The apparatus is also made in a portable form of iron, and placed on wheels.

Above the furnace is the door of a small fireplace, in which sulphur is burnt with a view to aid in the disinfection; the fumes entering the chamber through the iron grating which forms the floor. In the roof of the oven is an opening, by which, when a damper is pulled out, a communication is established with the ash-pit of the furnace; this forms an outlet for ventilation, the sulphur stove serving as the inlet. The fumes given off from the materials subjected to disinfection are thus made to pass through the fire.

Over the sulphur door is a pane of glass, through which a thermometer hung up inside the chamber can be read. There is also a thermometer (registering), enclosed in a long brass tube with a wooden handle; this fits into a hole in the oven door, the farther end of the tube, which is perforated to allow the access of heat to the bulb, projecting about 2 feet into the interior of the oven. By withdrawing the thermometer, the temperature can be read through a slit in the brass tube.

The following directions issued by the makers explain the mode of use of the apparatus.

> Close the vapour flue damper, open the ashpit door, and light the fire, feeding it with about three parts gas coke and one part coal, then place the wooden racks in position with the clothes or bedding lightly distributed over them.
>
> Close and fasten the entrance doors and place the long thermometer through hole in the same. Make up a slow fire until the heat inside the chamber is raised to 250° (which can be ascertained by the long thermometer), then open the vapour flue damper, close the ashpit door, and introduce sulphur or other disinfectants through the cast iron sulphur door over the furnace if desired.
>
> Keep the temperature at 250° for as long as may be considered necessary according to the thickness or description of the material to be disinfected, say from half an hour to one hour, but in no case must the temperature exceed 275°.
>
> N.B.—Should the apparatus at any time get overheated open the small cast-iron sulphur door until cooled down. The small thermometer will generally register less than the actual heat inside the chamber, and must, therefore, be used as a guide only.

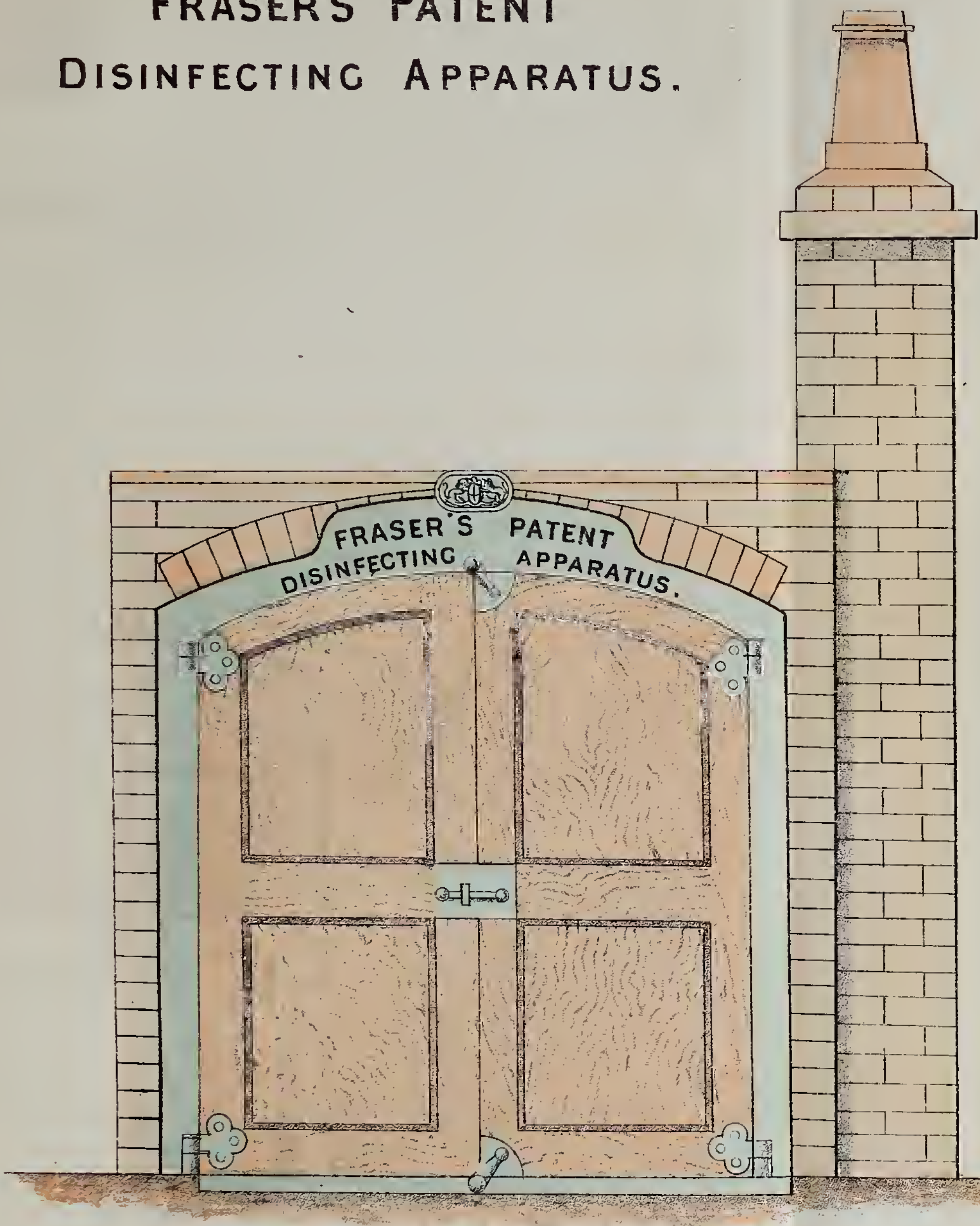
Experiments at St. Thomas's Hospital.

The following experiments were made with the oven at St. Thomas's Hospital. This has internal dimensions 7 feet deep from doors to back, 4 feet wide, and 4 feet high. There are doors at one end only; these are of wood lined internally with iron. There are three latticed shelves at quarter, half, and three-quarters of the height on which articles to be disinfected are placed.

Experiment 1.

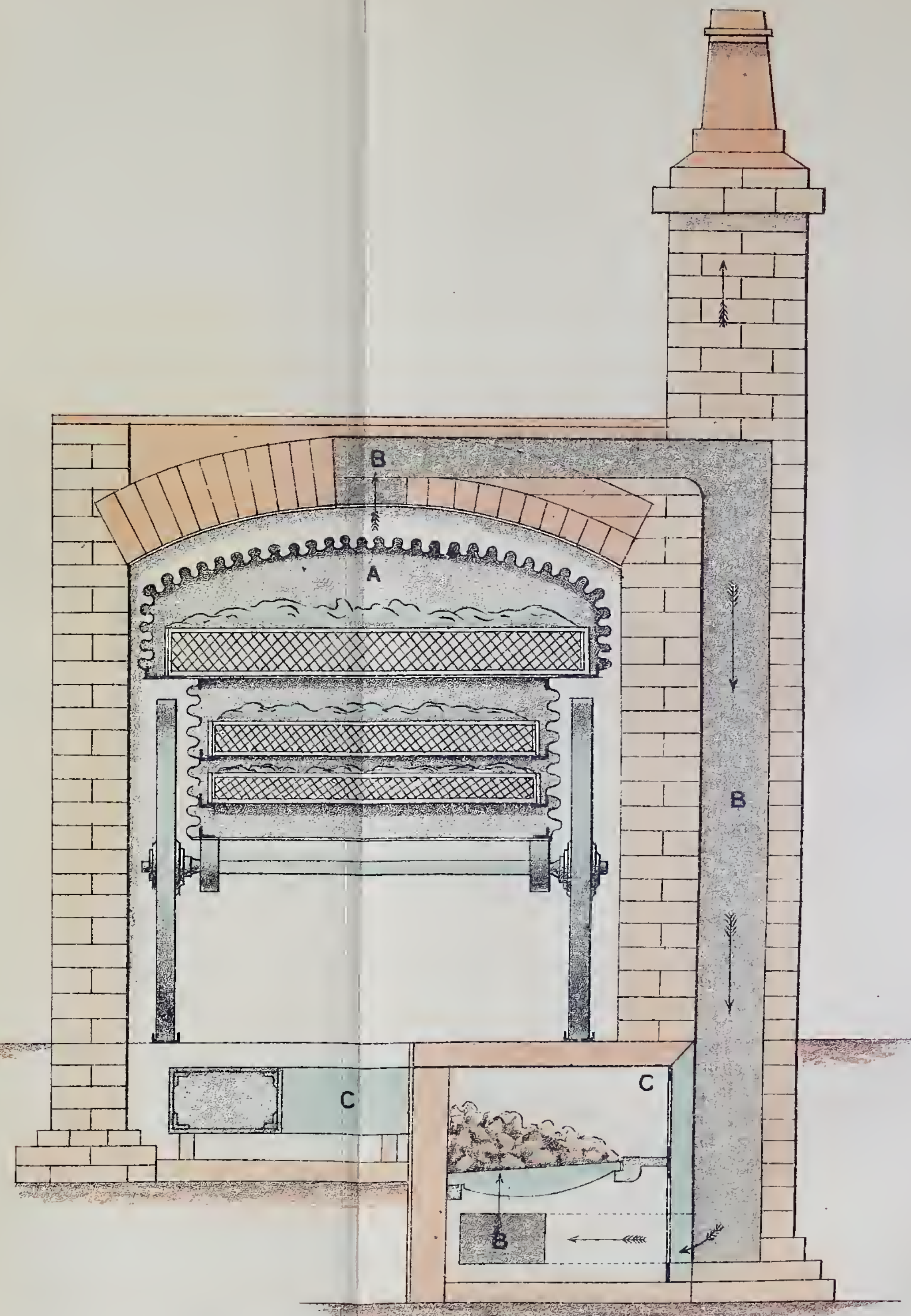
On February 12th the fire had been lighted at 7 a.m.; the stove had been in use in the morning of the previous day, but had been allowed to go out in the afternoon. At 10 a.m. the long thermometer had not

FRASER'S PATENT DISINFECTING APPARATUS.



FRONT ELEVATION.

A. *Carriage in which Infected Articles are conveyed.*
B. *Flue to draw Vapors from inside of Chamber through the Fire.*
C. *Furnace and Smoke-Flues.*



SECTION. *Through Chamber and Carriage.*

Scale ½ Inch to a foot.

W. J. FRASER & Cº Engineers,
Commercial Rᵈ London E.

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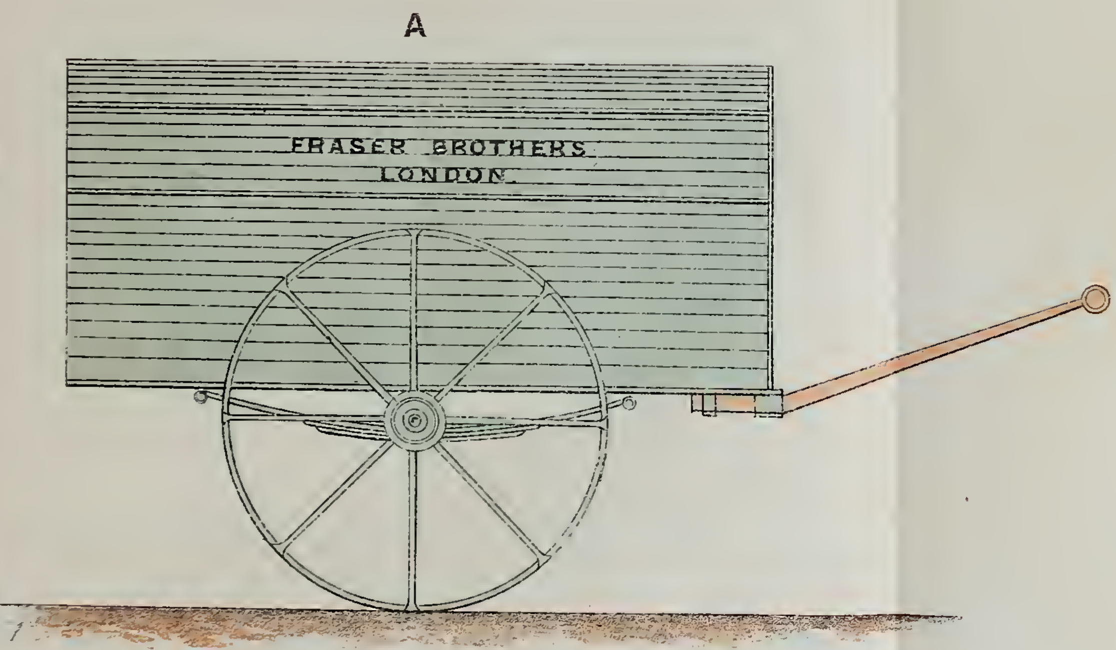
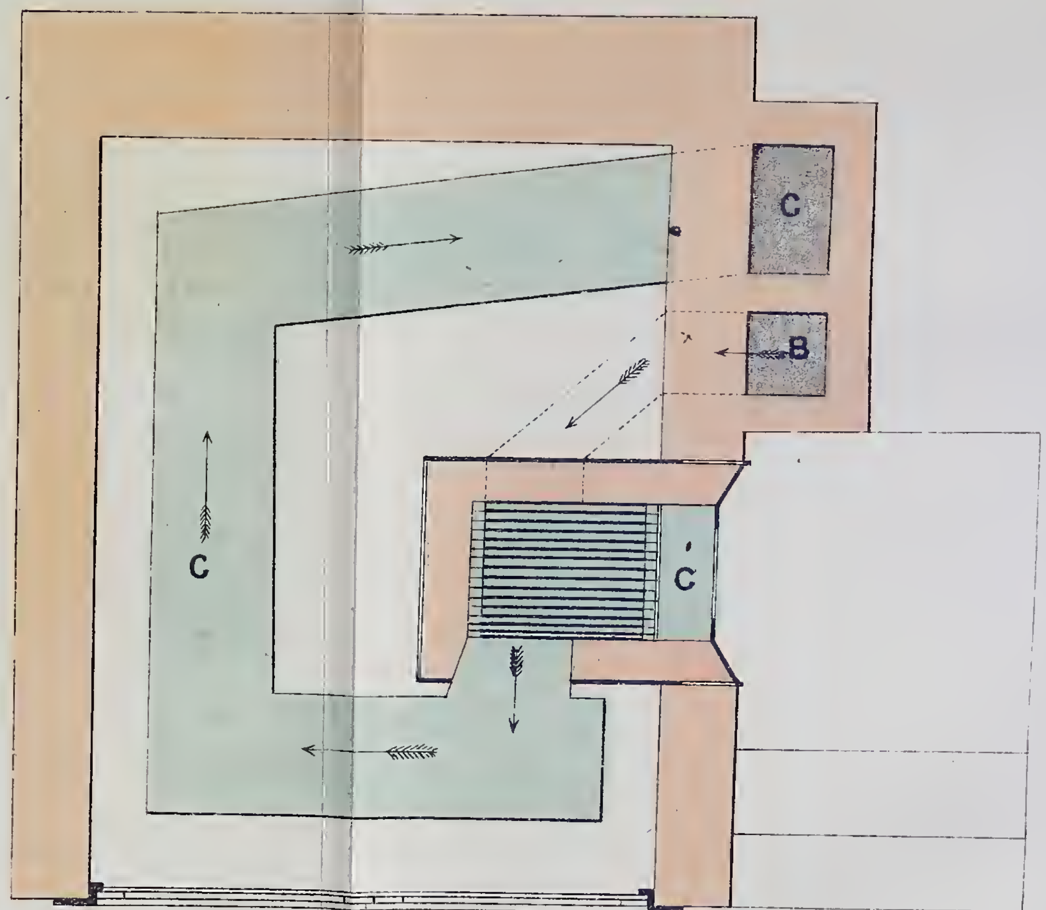
Fraser's Patent Disinfecting Apparatus.



CARRIAGE *Side Elevation.*



PLAN.

A. *Carriage in which Infected Articles are conveyed.*
B. *Flue to draw Vapors from inside of Chamber through the Fire.*
C. *Furnace and Smoke-Flues.*

Scale ½ Inch to a Foot.

W. J. FRASER & Co. Engineers.
Commercial Road, London, E.

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risen high enough to be read, and it was not till 12.30 p.m. that it had reached 210° F. Six registering thermometers were then placed in the oven, viz., two on the floor (front and back), two on the lower shelf, and two on the upper shelf, the middle shelf not being in place. In 40 minutes after the closing of the doors the long thermometer,—*i.e.*, that pushed through the door, and which projected 2 feet into the interior of the oven close under the lower shelf,—had risen to 250° F. (It may be observed that on the scale of this thermometer only the degrees 210, 250, and 275 are marked, so that of any other degree of heat only a rough approximation can be obtained.)

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The thermometers in the oven were found to read as follows :—

On floor -	front	-	264°
	back	-	308°
On lower shelf -	front	-	223°
	back	-	275°
On top shelf -	front	-	238°
	back	-	264°

These readings show that the temperature varies greatly in different parts of the interior of the chamber, there having been in this experiment 85° difference between the highest and lowest reading. The average of the six readings is 262°, which is about 12° above the highest point observed by the long thermometer. It seems probable that the brass tube in which this is enclosed may screen it to some extent from the heat radiating from the bottom. The apparatus at St. Thomas's did not at the time of my visit possess a thermometer hung so as to be read through the pane of glass over the furnace door, but it appears from the makers' directions, previously quoted, that the thermometer in this position does not, any more than the other, give correct information as to the temperature of the interior.

Experiment 2.

The following articles were placed on the midde shelf, as near the centre as possible :—

A. A flock pillow, weighing 4 lbs., with thermometer enclosed.
B. A feather pillow, weighing 3 lbs., with thermometer enclosed.
C. A flock pillow, weighing 6 lbs., with thermometer enclosed.

Another thermometer was laid upon the pillows.

The doors being closed, the temperature, as shown by the long thermometer, was maintained at as nearly as possible 250°, being read every five minutes; it once went up to 260°. At the end of an hour the thermometer laid on the pillows registered 201°, that in the smaller flock pillow 134°, and that in the feather pillow 275°.

The latter unexpected reading was, in all probability, attained owing to the bulb of the thermometer having shifted its place among the feathers, which were very loose, so as to come in contact with the heated layers near the surface which was undermost as the pillow lay on the shelf.

The flock pillow had lost about 3 ozs. in weight, and the ticking had acquired a brownish tinge from scorching in stripes where unprotected by the bars on which it lay.

The pillow (C) was allowed to remain in the oven until two hours had expired, when the thermometer inside it was found to read 138°. The ticking was scorched similarly to that of the other pillow.

Experiment 3.

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Some articles had been placed in the oven for disinfection for the purposes of the hospital in the usual manner.

A thermometer was placed between the folds of a horse-hair mattress which had been doubled in two, so that one half lay upon another, on the top shelf.

Another thermometer was placed between two pillows which had been laid one upon another, on the lower shelf.

Another thermometer was placed beside it, the bulb being over an interspace between the bars. The thermometer pushed through the door gradually rose from about 170° to 248°. When it had attained the latter temperature, and articles had been in the oven for an hour, they were taken out, being considered by the man in charge to be sufficiently disinfected.

The thermometer lying on rack registered		241° F.
That between the two pillows	„	122°.
That between folds of mattress	„	117°.

A wet and dry-bulb arrangement hung in centre of oven registered—

Dry bulb - - - -	228°
Wet „ - - - -	122°

It can hardly be supposed that an exposure to heat such as the above, can suffice for the effectual disinfection of articles of bedding.

Experiment 4.

On the following day, the fire having been lighted at 7 a.m., the long thermometer had reached 210° at 10.30 a.m.

On the lower shelf was placed the flock pillow, weighing 4 lbs., containing a thermometer. On the middle shelf were placed a bale of white cotton rags, weighing $61\frac{1}{2}$ lbs. (somewhat damp at one end), and a bale of woollen rags, weighing 59 lbs.; into each of these a hole was bored with an auger, and in this hole a thermometer was placed. Another thermometer was laid on the shelf beside them.

The bales and pillow were allowed to remain in the oven for six hours, and some other articles for disinfection were placed in it at the same time. It so happened that the attendant was called away to other duties, and in his absence the heat rose to such a degree that some woollen garments which were on the bottom were found on his return charred to tinder. The exact degree of heat was not noted.

At the end of six hours:—

The thermometer on middle shelf registered		272°.
That in bale of white rags	„	118°.
That in bale of cloth rags	„	99°.
That in pillow on lower shelf	„	298.

The white rags had lost $5\frac{3}{4}$ lbs. in weight, and the cloth rags $4\frac{1}{4}$ lbs.

The attendant in charge says that danger of scorching can only be avoided by not allowing the long thermometer to rise above 210°; if this be exceeded, injury is apt to take place.

On examining the wooden shelves on which articles to be disinfected are placed, each shelf was found to be much charred in one place, viz., at that which when the shelves are in place comes over the hottest part of the furnace. The attendant, however, states that this used not to be the case when the stove was new, and that it has only happened since some repairs were made to the floor.

Coke is used as fuel; the amount of consumption is not known.

Sulphur is only used when clothing infected with vermin, or from fever cases, has to be disinfected. A handful, perhaps 2 or 3 ozs., is then burnt in the small furnace provided for that purpose.

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This form of apparatus, if the one at St. Thomas's Hospital may be taken as a fair example—and I was referred thither by the makers—seems to possess the following serious disadvantages:—

The heat is very unequally distributed in the chamber; in Experiment 1 the thermometers showed 80° difference of temperature in different parts. The chamber and its contents, too, are heated by radiant heat proceeding from the hot floor, rather than by currents of heated air, hence different sides of an object are exposed to unequal degrees of heat; thus in Experiment 2 the underpart of a pillow was over 70° hotter than the upper surface.

Moreover, as before remarked, the thermometers supplied with the apparatus do not afford a correct indication of the actual temperature of the interior.

Another drawback, which it shares with other apparatus heated by solid fuel, is the difficulty of regulating the temperature, and the careful stoking and constant attention to the thermometer and valves which are required in order to prevent the heat from exceeding or falling below the desired point.

These disadvantages seem to be met with in practice elsewhere, as at Bradford and Derby (Dr. Thorne's Hospital Report, pp. 84 and 114), at the former of which places they have led to the apparatus being abandoned, and Ransom's self-regulating apparatus substituted. At Southport, however, where the apparatus was in charge of a skilled workman, Dr. Thorne states that it was found to answer satisfactorily (p. 248). Dr. Paddock Bate also states that the apparatus is perfectly efficient if well managed and carefully watched, but that the efficacy of the whole process depends upon the care of the attendant in charge, for unless he is constantly on the watch, the temperature rises too high, and the articles placed in the chamber get scorched. "After allowing "this to happen two or three times, and getting into trouble for it, the "attendant finds the simplest plan is to keep the temperature low, and "the process degenerates into a farce. I am told that articles have been "returned to the owner as thoroughly disinfected with this apparatus, "in which lice and bugs still remained alive." (Annual Report, G. Paddock Bate, M.D., M.O.H., Bethnal Green, 1883, p. 39.)

Experiments with portable apparatus.

Some further experiments were also made at Messrs. Fraser's works with an apparatus of the portable form. This portable apparatus is similar in principle to the fixed one, but differs in details of construction. It is in the form of a van, being placed on four iron wheels. The chamber is 7 feet long, 4 ft. 6 in. broad, and 3 feet high internally, and is of iron covered with felt and cased externally with wood. At one end there is a furnace, with a sulphur door over it as in the fixed form, also two side doors for cleaning out the flues. At the other end is the short iron chimney, and at this end shafts can be attached, by which the machine can be drawn about from place to place as required. The temperature of the interior is indicated by a pyrometer at the side, the rod of which projects across the chamber an inch or two above the heated bottom; the rod is enclosed in a brass tube connected with a mass of brass on the outside. There are three sliding wooden latticed shelves as in the fixed apparatus, and flues by which vapours arising in the interior can be carried into the hearth of the furnace.

The following experiments were made:—

Experiment 1.

On May 27th, 1885, the fire had been lighted at 11 a.m., and at 12.30 the pyrometer had reached 300° F. A flock mattress three inches thick had been placed on the middle shelf.

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(*a.*) Seven thermometers were placed in different positions and the doors closed at 1.15. The pyrometer had then fallen to 190°, but at 2 p.m. it had risen to 310°.

The thermometers were then found to read:—

1.	On top shelf next door	- - -	249° F.
2.	Ditto middle (over mattress)	-	228° (about).
3.	Ditto far end	- - -	298°.
4.	On lower shelf, near door	- - -	295°.
5.	Ditto middle	- - -	325°.
6.	Ditto far end	- - -	292°.
7.	On bottom by pyrometer	- - -	382°.

A thermometer in the mattress (which had been in the oven $2\frac{1}{4}$ hours) indicated 220° F.

(*b.*) The experiment was repeated after the withdrawal of the mattress. The pyrometer had then fallen to 140°, but in half an hour it had risen to 300°.

The thermometers indicated:—

1.	Top shelf near door	-	256°.
2.	Ditto middle -	-	258° (about).
3.	Ditto far end -	-	273°.
4.	Lower shelf, near door	-	246°.
5.	Ditto middle	-	296°.
6.	Ditto far end	-	?(index displaced in withdrawing.)
7.	Slung on pyrometer rod	-	370°.
8.	Middle shelf, middle	-	266° (about).

(*c.*) In another similar experiment, after 40 minutes' exposure, during which the pyrometer rose from 260° to 300°, the thermometers inside the chamber were found to register:—

1.	Top shelf, near door	- - -	246° F.
2.	Ditto middle	- - -	262° (about).
3.	Ditto far end	- - -	248°.
4.	Lower shelf, near door	- - -	250°.
5.	Ditto middle	- - -	293°.
6.	Ditto far end	- - -	244°.
7.	Ditto at side, mid length	- -	269°.

In the first of the above experiments the thermometer No. 2 was shaded from the heat by the mattress below it, and Nos. 7 in the first and second were in a position in which articles for disinfection would not be likely to be placed. Excluding these from consideration, we find in each experiment a difference of about 50° F. between the highest and lowest readings of the several thermometers, the highest in each case being that in the middle of the lower shelf. The under-side of this shelf was scorched in this place.

The temperature shown by the pyrometer was nearly the same as that registered by a thermometer placed in this position, but was very far below that shown by a thermometer placed in the immediate neighbourhood of the pyrometer rod. The pyrometer rod, it is to be noted, is placed in the hottest part of the chamber, but on the other hand there is a considerable loss of heat through the connexion of the brass tube in which it is enclosed with the brasswork outside. Either these two sources of error in opposing directions nearly balance each other or the pyrometer has been purposely adjusted to indicate the temperature existing in the middle of the chamber and not that where it is placed. At any rate it forms a more trustworthy guide to the internal temperature than did the long thermometer in the other form of the apparatus.

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Experiment 2.

A new flock pillow, weighing $4\frac{1}{4}$ lbs., and enclosing a thermometer, was placed in the oven in the centre of the middle shelf. Another thermometer was laid beside it, and the wet-and-dry bulb arrangement was suspended in its neighbourhood, and the door was closed.

Time.	Pyrometer.	Remarks.
2.35	300° F.	Door closed.
2.50	310	——
3.5	315	——
3.20	318	Dry bulb thermometer registered 299°. Wet ditto ditto 146°.
3.35	310	Pillow removed.

The thermometer by the pillow registered 318°, that inside the pillow 136° F. The pillow case was scorched in stripes, corresponding to the interspaces of the bars on which it lay.

Experiments with addition of steam jet.

By the courtesy of Messrs. Fraser I was enabled to make some experiments for comparison with the above with the same apparatus, but with the addition of a jet of steam conveyed by a flexible tube from a boiler in their works, and introduced into the apparatus through an opening near the floor. The pressure of steam in the boiler ranged from 20 to 30 pounds. The temperature indicated by a thermometer held in the jet as it issued from the nozzle of the pipe was 204° F.

Experiment 3.

A pillow exactly similar to that used in Experiment 2 was placed in a similar position on the middle shelf, a thermometer being placed by it, and a wet-and-dry-bulb arrangement suspended as in the former case.

Time.	Pyrometer.	Remarks.
3.45	270° F.	Door closed, and a small amount of steam admitted.
3.55	310	(The temperature rose rapidly on the introduction of a small jet of steam, and continued high in spite of reducing the fire and opening all the ventilators).
4·	310	
4.5	335	
4.10	320	
4.15	315	
4.20	300	Door opened and wet-and-dry-bulb thermometers read and replaced. Dry bulb - 299°. Wet bulb - 165°.
4.25	260	——
4.30	260	More steam turned on.
4.35	190	——
4.40	185	——
4.45	190	Doors opened.

Results:—

Thermometer by pillow registered	- - -	299°
„ in pillow ditto	- - -	188
The dry bulb thermometer	since replaced at 4·25 had reached	250
The wet ditto		189

The pillow case was slightly scorched between the bars, but much less so than in the former experiment.

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Experiment 4.

The experiment was repeated another day with the same pillow placed as before; a thermometer being placed by it and another laid on it.

Time.	Pyrometer.	Remarks.
1.40	250° F.	Door closed. No steam.
1.55	280	Door opened { Thermometer by pillow - 264°. Ditto on pillow - 228°.
2.0	275	Steam turned full on, and wet and dry bulb thermometers inserted.
2.5	200	——
2.10	195	——
2.15	190	——
2.20	190	{ Dry bulb thermometer - 249° F. Wet ditto - 190° F.
2.25	180	Thermometers re-inserted.
2.30	175	——
2.35	185	——
2.40	188	Door opened.

Results :—

Thermometer by pillow registered - - -	264°
„ on ditto - - -	240°
„ in ditto - - -	209°
Dry bulb thermometer - - - -	258°
Wet bulb - - - - - -	102°

The pillow case showed no further signs of scorching.

These experiments, corroborated by others made by Messrs. Fraser, appear to be conclusive as to the gain in respect of penetration of heat obtained from the use of steam to moisten the air of the chamber. Thus, in Experiment 2 a pillow was exposed for an hour to a temperature of from 300° to 318°, with the result that only 136° was attained in its interior, while in Experiment 4 the temperature of the chamber not having exceeded 264°, the duration of the experiment and other circumstances being the same, with the exception of the introduction of the steam jet, a heat of 209° was obtained inside the pillow. Had the steam been on for the whole of the time, a temperature of over 212° would doubtless have been obtained.

The increase of humidity of the air in the chamber, with the introduction of the steam jet, is shown by a comparison of the reading of the wet and dry bulb thermometers.

——	No Steam.	Little Steam.	Much Steam.		
Dry bulb - -	299	299	250	249	258
Wet bulb - -	146	165	189	190	192

The first introduction of a little steam was followed by a rise of the pyrometer, seemingly due to the introduction into the chamber of heat from an extraneous source. A larger jet of steam, however, caused the pyrometer to fall rapidly, nor could it be got to rise again above 190° so long as the steam was on, however large a fire might be kept up, although

it rose at once when the steam was turned off. At the same time the temperature, as recorded by thermometers in the chamber when steam was used, was considerably higher than that shown by the pyrometer. The explanation of these at first puzzling circumstances was at length found to be that the water condensing in the flexible pipe was blown out by a forcible jet of steam, and fell in spray upon the pyrometer rod, which it cooled by evaporation. A small jet of steam did not carry the spray far enough to reach the pyrometer rod.

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Experiment 5.

The following experiment was made with a view to ascertain whether the introduction of the steam jet made any difference in the distribution of heat in the chamber. Six thermometers were placed in different positions on the shelves:—

At 5.0	pyrometer stood at	210°	door closed and steam turned on.
„ 5.5	„	200°	
„ 5.10	„	180°	
„ 5.15	„	180°	
„ 5.20	„	175°	steam turned off.
„ 5.25	„	200°	
„ 5.30	„	235°	door opened.

The thermometers were found to read as follows:—

On top shelf, near door	- -	238°
„ middle	- -	234°
„ far end	- -	254°
On lower shelf, near door	- -	242°
„ middle	- -	270°
„ far end	- -	242°

Thus there was only 36° difference between the readings of the highest and lowest instead of 50° as in the first experiments: the more equable distribution of temperature may have been due to the circulation of air caused by the steam jet, or to the cooling of the heated bottom by the condensed water falling on it.

The fuel used was coal. 24 lbs. were consumed in raising the temperature to 300° (in an hour and a half) and 56 lbs. in the whole six hours' working.

The apparatus weighs about four tons, and takes two horses to draw it.

I am informed that the portable apparatus is in use in many places and gives satisfaction; but it appears to possess similar drawbacks to the stationary form.

In Dr. Thorne's Hospital Report (p. 86) it is stated to be in use at the Isle of Thanet Joint Hospital, but to have been subsequently fixed in a brick building. " It is admitted that it does not answer its " intended purposes, except at the risk of scorching articles. Indeed, " the sanitary authorities have already been obliged to make good " clothing and other articles which have been damaged. Sulphur is burned in the apparatus whenever it is used." I learn that this apparatus has now been abandoned, and Ransom's stove substituted.

Dr. E. F. Fussell, medical officer of health for East Sussex, informs me that Fraser's portable apparatus has been in use for two years in the Cuckfield Rural Sanitary District. It is kept at the workhouse, and is taken to any part of the district in which infectious

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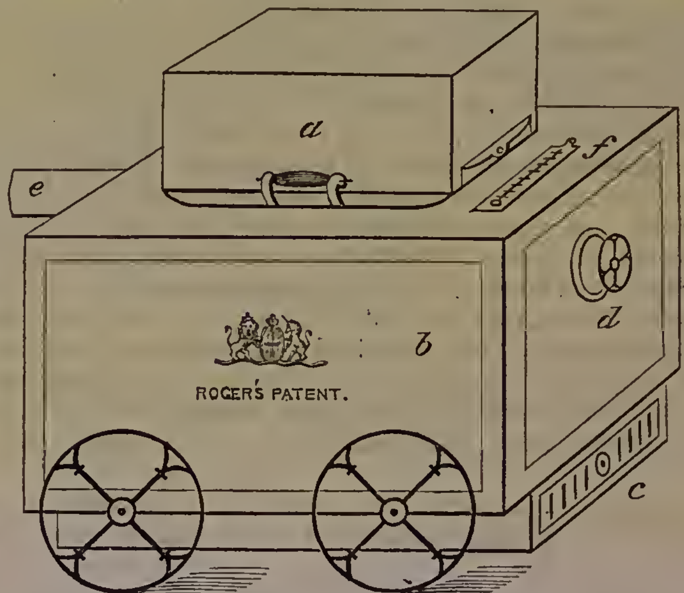
disease may occur. It has proved of great use, and Dr. Fussell thinks that for use in a rural district a portable apparatus has distinct advantages of convenience and safety over a stationary one. The inspector of nuisances who has charge of it states, however, that "articles which are placed on the bottom rack, if allowed to remain more than 12 or 15 minutes, will burn; this is a great drawback."

Dr. Heron Rogers's Portable Disinfecting Chest.

(Maker, Bradshaw, Retford.)

This apparatus is in use at the East Retford Union Workhouse.



Explanation.—*a*. A loose wooden box, by which clothing, &c., is brought from the sick-room without danger of infection. *b*. Hot air disinfecting chest. *c*. Fire or other heating agent. *d*. Fresh air valve, by which noxious vapours, &c., are forced into chimney, *e*, which is connected with an ordinary flue or pipe. *f*. Thermometer.

It is a rectangular iron chest, 3 ft. 6 in. long, 2 ft. 6 in. broad, and 2 ft. 9 in. high, mounted on four iron wheels, and with a handle at one end (not shown above), by which it can be pushed about from place to place. The sides, ends, and bottom are double, and in the bottom there is at one end an opening in the outer casing, under which a fire-box is slid; the products of combustion ascend in the interspace between the casings, and find an exit by a flue at the end opposite the fire-box. This flue was originally 4 ft. 6 in. high, but for the sake of a better draught the height in the apparatus at Retford has been increased to 8 ft. 4 in.; it can be removed for facility of carriage. The lid of the chest is a sliding plate of iron. A box, *a*, with a sliding lid is provided for the conveyance of infected articles; this box is intended to be inverted over the mouth of the chest, when the lid being withdrawn the articles within are allowed to fall out upon brackets in the interior of the chest. It has been found, however, that clothes in so falling are apt to touch the bottom and get burnt, and hence the box is not now used, the clothes being hung by hand on an arrangement of bars. A flag-stone has been fixed inside the chest over the position of the fire-box, as that part of the bottom is apt to get unduly heated. An iron lattice has also been added to prevent articles touching the bottom. In the top of the chest, at the end above the fire-box, a thermometer is fixed, the bulb encased

in an iron tube extending downwards 6 inches into the interior of the chest. The scale is enclosed in a wooden case with sliding lid.

On Disinfection by Heat; by Dr. Parsons.

There is a small communication constantly open between the interior of the chest and the flue, and when a current of air through the chest is desired, another aperture, *d*, serving as an inlet can be opened. The flue has a throttle valve to regulate the draught. There is also a damper, by which the opening at the bottom can be closed when the fire-box is removed. Coal is used as fuel.

The machine was devised by the inventor with reference especially to its use in small towns and rural sanitary districts. Being portable, it could be wheeled into the yard of an infected house, and any articles requiring disinfection could be disinfected there and then without being taken off the premises; or in case of an outbreak of infectious disease in a village, the machine could be taken there and left as long as required, so that there would be no necessity for carrying infected articles to another, perhaps uninfected, place, as must happen if there were a single stationary apparatus for the whole of a wide rural district.

The apparatus at Retford, however, has only been used on the workhouse premises and for workhouse purposes, chiefly for killing vermin in the garments of tramps, which it does effectually. I learn from the master of the workhouse that the apparatus cost 18*l*., and could now probably be made for less; but that during the nine years that it has been in use, the repairs which have from time to time been needed have cost in the aggregate considerably more than the original price of the machine. The iron plates soon get burnt through, and have had to be replaced by thicker ones. The machine is used, perhaps, three times a week.

The temperature employed, as shown by the fixed thermometer, is about 231° F., or midway between 212° and 250° F. (the intermediate degrees not being marked on the scale), this temperature being considered to correspond to one of 250 in the interior. It takes about an hour from first lighting to attain this temperature, and when reached it is maintained for about 20 minutes.

The following experiments were made on May 18th, 1885:—

Experiment 1.

The fire having been lighted at 12.40, the fixed thermometer at 1.35 had reached a point about 235° F. Four registering thermometers which had been placed inside were then found to read as follows:—

1.	On upper bars, near end over fire-box	273°
2.	Ditto end next flue	274°.
3.	Suspended near bottom, under 1	277°.
4.	Ditto ditto under 2	282°.

Experiment 2.

Six thermometers were inserted. The fixed thermometer, which had fallen below 212°, in a quarter of an hour from the closing of the lid had risen to about 242°. The thermometers were found to read:—

1.	On top bars, middle of chest	270°.
2.	Ditto end next fire-box (as 1 in Experiment 1)	278°.
3.	On bottom rack, under 1	328°.
4.	Ditto under 2	302°.
5.	Near bottom, in corner	260°.
6.	Ditto near side wall, mid length	290°.

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These experiments show that as in other chambers in which the heat is applied directly to the walls or side there is considerable variation in temperature between different parts of the interior; in Experiment 1 in which the thermometers were placed only in the more central parts, there was it is true only a variation of 9°, and indeed in so small a chamber there is not room for so great a difference as in larger ones, but in Experiment 2 there was a difference between highest and lowest readings of 68°.

It is shown also that as in other apparatus in which the fixed thermometer is similarly placed, it fails to give any correct indication of the temperature in the interior; much of the heat falling on the iron tube in which the thermometer is encased does not reach the bulb, but is conducted to and diffused in the mass of metal with which the tube is in contact. This not only causes the thermometer to give too low a reading, but also renders it sluggish; it continued to rise for some time after the fire-box had been entirely removed, and to fall after the fire had been replaced.

Experiment 3.

A flock pillow weighing $3\frac{1}{2}$ lbs. was hung from the centre bar. A thermometer was inserted in the pillow and another one hung beside it. On the bars was placed a woollen rug folded in four, a thermometer being placed between the middle folds.

Another rug folded in eight, with a thermometer between the two middle folds, was placed on the former, another thermometer being laid upon the top of all. Another thermometer was hung in the corner of the chest, in the same position as No. 5 in Experiment 2.

The lid being closed, the temperature, as shown by the fixed thermometer, was maintained for half an hour between 225° and 232°.

The thermometers were found to read :—

1. In corner - - - - - -	245°.
2. On rugs - - - - - -	182°.
3. In top rug - - - - - -	149°.
4. In lower rug - - - - -	193°.
5. By pillow - - - - - -	235°.
6. In pillow - - - - - -	148°.

The rugs steamed as if they had been slightly damp, although they did not feel so when put in. Neither they nor the pillow were injured.

Experiment 4.

The following articles were placed in machine :—A flock pillow weighing 3 lbs., suspended as former with a thermometer within, and another by the side of it.

A tramp's waistcoat and coat hung over the bars, with a thermometer in the pocket of each.

These were heated for an hour. In spite of opening the ventilator and partially withdrawing the fire-box, the fixed thermometer rose to above 260°, and to prevent it going higher still the fire-box had to be entirely removed. At the end of the hour the thermometer recorded—

1. By pillow - - -	289°
2. In pillow - - -	165°
3. In waistcoat - - -	304°
4. In coat - - -	262°

The pillow was slightly scorched on the side towards the bottom of the chest; the other articles did not show evident injury. The lice and their eggs, with which they were infested, were dead and shrivelled up.

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The master informs me that scorching of articles has sometimes taken place, and is very apt to do so, unless care be exercised to avoid placing the articles so that they touch the bottom, and to prevent the temperature rising too high.

The liability to scorch seems to have been met with elsewhere, and at Newark the use of the apparatus has been abandoned on this ground. The medical officer of health for Penzance, however, informs me that the apparatus has been in use in that borough for several years, and that he is perfectly satisfied with it, and in no case has there been any spread of disease by clothing which have been subjected to its action. It is used under the personal superintendence of the inspector of nuisances, who says: "In our first experiments (the thermometer "attached registering only 212°) we had to increase the temperature to "effectually disinfect, and not knowing when we were above 212°, we "sometimes found articles scorched, to prevent which we lined the chest "inside with wood trellising fastened with copper." By this means the difficulty is said to have been overcome. The portable apparatus is considered more convenient than a fixed one, as, where there is room, it is always taken to the infected house instead of bringing infected articles through the town to the apparatus.

It would seem that though this apparatus possesses the drawbacks common to those of its class, it is capable of doing useful work under efficient superintendence, and its cheapness and portability may recommend it for use in rural and small urban districts, for which a large or costly apparatus would be inapplicable.

Dr. Langstaff's Disinfecting Chamber.

In the International Health Exhibition a model was exhibited by the late Dr. Langstaff of a combined bath-room and disinfecting chamber, designed for the use of nursing institutes, the object being that after attendance on an infectious case, the nurse shall cleanse her person and at the same time leave her clothing for disinfection, so as to avoid any risk of carrying infection to the next patient on whom she may have to attend.

Dr. Langstaff's disinfecting chamber for Nurses Institute

Learning that an appliance of this kind was in use at the Hampshire Nurses Institute at Southampton, I obtained permission to see it.

The building consists of a bath-room and a hot-air chamber; the former contains a bath with hot and cold water laid on; the hot water is heated by the same fire which heats the hot-air chamber.

The hot-air chamber closely resembles Fraser's. It is heated by a fire underneath; the furnace door was originally in the bath-room, but on account of the obvious disadvantages attending this arrangement, it has since been removed to the outside, where a small lean-to serves as the stoke hole. The chamber, which is about 8 feet square, is entered from the bath-room by a sliding iron panel, in which is fixed a small pane of glass. The floor of the chamber is partly of masonry, partly formed by iron gratings; under the latter the flue from the furnace passes in a series of zigzags and finally ascends in one corner to end above the roof. The walls of the chamber are of brick, the roof is of corrugated iron, covered with sand. In the walls are iron ledges on which rest bars for the support of articles of clothing. In a bar near

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the door is a slit, in which is placed a thermometer in such a position that it can be read through the pane in the door. There is an inlet aperture near the floor, and an outlet into the open air at the top of the chamber; these can be opened or shut by valves. There is also a damper in the furnace flue, by which the draught of the fire can be regulated.

The fuel is coke; the cost about 1*s.* 6*d.* for each time of heating.

The whole building cost about 100*l.*, but it has required frequent repairs since its erection in 1878, and 15*l.* were spent in altering the flues last year.

From a note-book kept by the matron, I gather that the apparatus was used 17 times between December 14th, 1883, and January 17th, 1885; that before the alterations to the flues were made in the summer of 1884 the average time required from the lighting of the fire to get up a temperature of 212°, as shown by the thermometer in the chamber, was 7½ hours, on one occasion as much as 13½ hours, while since the alterations the average time has been 5 hours. The matron states that the time required varies with the force and direction of the wind, and also depends upon whether the chamber has been used lately or not. It appears also from these notes that on several occasions clothes and other articles have been scorched. On the occasion referred to in which 13½ hours were required to get up the heat, a note by the matron states, "Linen scorched and gloves and books spoiled, though the "thermometer could not be got higher than 192°."

Experiments.

Experiment 1.

On February 16th the fire had been lighted at 12 noon. At 3.30 the thermometer by the door stood at 60° F. Six registering thermometers were placed in different parts of the chamber and the door was closed at 4 p.m. At 5.25 p.m. the thermometer belonging to the apparatus had reached 212°.*

The thermometers inside were taken out and found to read as follows:—

1.	Close to ceiling, in centre			288°
2.	On bars at mid-height, end next furnace over brickwork			268°
3.	Ditto ditto	middle, over grating		273°
4.	Ditto ditto	far end	ditto	272°
5.	Hung 1 foot above floor (grating)			286°
6.	Hung free in chamber, near middle			269°

When the fire is burning well, the part of the flue nearest the furnace is seen through the grating to be red hot, and the water in the hot-water cistern, which is in the corner of the chamber, boils violently; so much so, that special means of escape have had to be provided for the steam to prevent it becoming an annoyance to neighbours.

Experiment 2.

A thermometer was inserted in a flock pillow weighing 4 lbs., which was placed on bars in the centre of the oven.

Another thermometer was laid near it in the position of 3 in the previous experiment. Another was suspended over the red-hot flue, about 2 feet above it. Another was hung in the corner near the upright flue.

---

* There was some doubt as to whether this thermometer was correct, the scale having at one time been found to be loose. Plunged in boiling water, however, I found it to stand at 212° F.

The doors were shut at 5.45. At 6.35 the thermometer belonging to the apparatus had got up again to 212°, and it was kept as near that point as practicable, varying between 200° and 218°, until 8.15.

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The thermometers in the chamber were then found to register as follows:—

Over hot flue - - -	334°
Near upright flue - - -	267°
On bars by pillow - - -	280°
In pillow - - - -	147°

The pillow-case was somewhat scorched on the under side in the spaces between the bars.

From these experiments it will be seen that this apparatus presents the same disadvantages as Fraser's, viz., the inequality of heat in different parts of the chamber; the misleading indications of the thermometer provided with it; and the need of the constant attention of a careful stoker all the time that it is in action in order to keep the temperature uniform.

The position of the thermometer is particularly inconvenient. It is in the coolest part of the oven; it bars the entrance to the interior; and it cannot be read by the stoker while the bath-room is in use.

The combination, however, of bath-room and disinfecting apparatus seems a useful one for institutions of this kind. Probably a more convenient arrangement would be a small self-regulating gas oven for disinfection, and an "instantaneous heater" or other contrivance heated by gas for warming the water for the bath.* The services of a stoker might thus be dispensed with, and the bath would be ready for use at any time.

Bradford's Patent "Safety" Disinfecting Apparatus.

(Makers, Thomas Bradford & Co., Salford, Manchester.)

Bradford's disinfecting apparatus.

This apparatus differs much in appearance and arrangement from any other which has come under my notice. As exhibited in action at the International Health Exhibition, it consisted of two parts, the base and the container. The base was divided longitudinally into three compartments, of which the central one was the heating chamber, and the two side ones were for ventilation, being made to communicate with the fire-chamber by slide valves. The fire-chamber had a door at one end and a flue at the other. The fire was contained in a waggon running on wheels which could be drawn out for convenience of stoking. As fuel Mr. Bradford prefers peat, but coal, coke, or charcoal may be used. The roof of the fire-chamber was formed of hollow iron bars, triangular in section, and open at the ends, for the purpose of affording a large heating surface. The remainder of the base was covered with a layer of sand upon which the container rested. The container was a large rectangular iron box, covered with non-conducting composition, open below, and suspended by chains and counterpoises from pillars at each corner of the base, after the manner of a gas-holder. There was a hole in the roof for ventilation, which could be opened or closed by a valve; and there was a thermometer at the side, the bulb of which projected a little way into the interior.

The articles to be disinfected are placed on a galvanized iron rack which stands on the base over the fire-chamber, and when in position

* In using such contrivances a flue should always be provided to carry off the products of combustion of the gas into the outer air. Many fatal accidents through suffocation have occurred where these products have been allowed to escape into the air of the bath-room.

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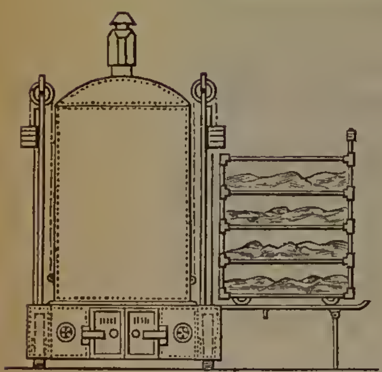
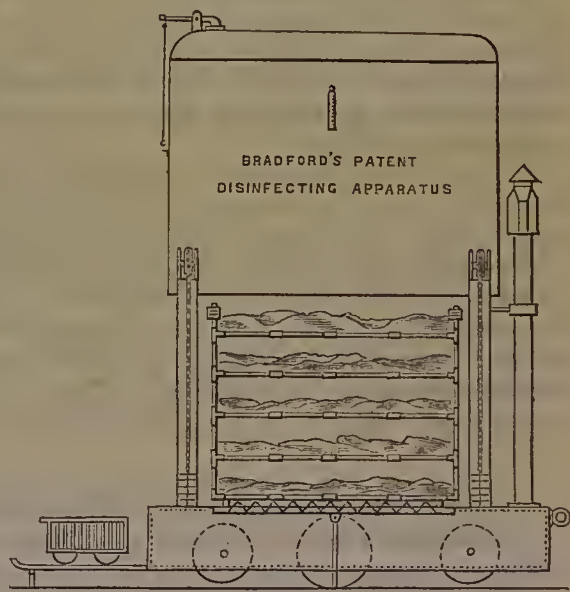
the container is let down over them and rests on the base, forming with the sand a sufficiently close joint.

The base was made to run on wheels so that the apparatus could be wheeled from place to place if required.

The rack was made of tubes to serve for the admission of steam into the container. A large shallow vessel containing water was placed at the bottom over the fire-chamber, so as to give off vapour and keep the air in the container moist. Mr. Bradford believes that this moistening of the air not only preserves fabrics from injury at a high temperature (say 250° F.), but also materially aids the process of disinfection.





Experiments at Health Exhibition.

The following experiments were made on July 8th, 1884:—

The fire had been lighted at 8.30 a.m.; at 11 a.m. the thermometer fixed in the side of the container stood at 220° F.; the apparatus had, however, been opened several times.

Experiment 1.

Seven registering thermometers were placed in the machine as under, and it was closed at 11.15. Opening the machine had caused the fixed thermometer to fall below 200°; at 11.45 it stood at 219°, it then fell on putting fuel on the fire to 212°, and had again risen to 223° at 12.15, when the machine was opened and the thermometers were found to read as follows:—

1.	On lower shelf of rack, at far end - -	224°
2.	Ditto ditto at end next the fire	248°
3.	On top shelf of rack, at far end - -	228°
4.	Ditto in middle - -	230°
5.	Ditto at end next the fire -	233°
6.	Suspended at mid-height at end next fire -	232°
7.	Suspended 1 foot below roof of container -	228°

There was thus 24° difference between the highest and lowest readings, these being both on the lower shelf; in the remainder of the machine the readings were fairly equable, and about 7° above the highest temperature indicated by the fixed thermometer.

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Experiment 2.

The following articles were then placed in the machine :—

(*a*.) A flock pillow, containing a thermometer pushed well into it.

(*b*.) A bag of cotton waste weighing about 30 lbs., with a thermometer embedded in centre.

(*c*.) Two straw palliasses laid flat with a thermometer lying between them.

The machine was closed at 1.20.

The fixed thermometer indicated as follows :—

1.20	-	-	220°
1.30	-	-	227°
1.35	-	-	230°
1.45	-	-	239°
1.50	-	-	240°

It then remained at or about 239° until 3 p.m., when the machine was opened and a wet and dry bulb arrangement of registering thermometers was hung in a position close to that of thermometer 1 in the previous experiment. The opening of the machine caused the fixed thermometer to fall to 210°, and it did not again rise above 230°; at 3.30 p.m. it marked 215°. The machine was then opened, and the following results were found :—

Thermometer in pillow registered	-	-	-	217°
Ditto in cotton waste	-	-	-	210°
Ditto between palliasses	-	-	-	202°
Dry bulb thermometer	-	-	-	220°
Wet bulb	-	-	-	184°

The results must be considered satisfactory, and led me to think that the moistening of the air by the steam had an appreciable effect in aiding the penetration of the heat. In Ransom's stove, at a temperature of 252° in dry air, a thermometer in a similar pillow had, in five hours, attained a temperature of 227°, or 25° below that of the chamber; in Bradford's the thermometer in the pillow had attained a temperature about as many degrees below that of the chamber in two hours. On the other hand, in steam under pressure at 240°, the thermometer in the pillow reached 234° in ten minutes.

The air in Bradford's machine on the occasion of the above experiments was sufficiently moist to form visible vapour when the valve was opened on a warm summer's day. Its humidity is also shown by the comparatively small difference between the readings of the wet-bulb and dry-bulb thermometers. Compare the figures with those found in Leoni's apparatus :—

		Bradford's.	Leoni's.
Dry bulb, maximum	-	220°	360°
Wet bulb, ditto	-	183°	161°
Difference	-	37°	199°

In another experiment the maximum registered in the machine having been 232°, the temperature of the water in the vessel was found to be 198°—difference 34°.

Experiments with later form of machine.

On a subsequent occasion (April 15th, 1885) some further experiments were made by me at Messrs. Bradford's works with another apparatus of the same kind, which had been constructed by them for St. Bartholomew's Hospital laundry at Swanley.

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This apparatus, though generally similar to that at the Health Exhibition, differed in the following respects:—The base is fixed, not on wheels. The furnace is of brick with a firebrick bridge (not a moveable waggon), and occupies the greater part of the base, the cellular bars projecting beyond it so as to cover nearly the whole area. Above these are two large flat iron evaporating vessels with inflexed sides to prevent boiling over. The water in these is maintained at a constant level by a pipe communicating with a feeding cistern outside. Above the evaporating dishes is an iron plate covered with asbestos, to cut off direct radiation from the heated base.

The container, which measures 8 feet long, 4 feet wide, and 4 feet 6 inches high, is raised by a crab with worm-wheel instead of being counterpoised; it fits, as in the other, on a sand joint. The iron horse on which clothes, &c., are placed, slides out at the side, on wheels running in iron grooves. If it were desired to provide separate entrance and exit this might be done, as Mr. Bradford points out, by dividing the building, by two pairs of folding doors, into three compartments, the container being placed in the centre compartment, and approached by opening the doors on one side or the other according as articles had to be placed in it or removed. (*See* Figures.)

The following experiments were made:—

Experiment 1.

The fire had been lighted at 10 o'clock. There was no water in the evaporating dishes. Seven registering thermometers (including a pair arranged as wet and dry bulb) were placed in different positions as below, and the machine was closed at 10.55. It was not until 12.40 that the fixed thermometers, of which there were two, one at either side, indicated 250°. The container was then lifted, and the enclosed thermometers were found to register as follows:—

1. In centre, at bottom. on rack just above asbestos plate - 322°
2. Ditto mid-height (dry bulb) - - Above 320° (broken through overheating).
3. Ditto ditto (wet-bulb, water all evaporated) - 236°
4. Ditto level of top bars - - - - 350°
5. Mid-length, on bottom, at side, projecting beyond asbestos-covered plate - - - - - - 471°
6. Mid-length, at side, mid-height - - - - 334°
7. At bottom, far end, beyond asbestos plate - - 344°

This experiment showed the temperature of the interior to be very unequally distributed, and to be considerably higher (about 100°) than was indicated by the fixed thermometers. When removed and immersed in boiling water, the fixed thermometers stood at 212°; their failure to indicate the correct temperature when in place seemed to be due to the fact that each was enclosed in a massive gun-metal case to which the tube surrounding the bulb was screwed. Hence much of the heat falling on the tube would be conducted through the wall of the container to the mass of metal on the outside, from which it would be dissipated into the air; the bulb of the thermometer would therefore be to a considerable extent screened from the heat by the tube in which it was placed.

Experiment 2.

A pyrometer, with a metal rod 3½ feet long, having been procured, it was fixed into the container in such a manner that the rod projected half-way across it close under the roof.

BRADFORD'S PATENT.

No. $\frac{3}{1756}$

"SAFETY" STEAM VAPOUR DISINFECTING CLOSET.

FRONT ELEVATION.

SIDE ELEVATION.

Scale, 8 Feet = 1 Inch.

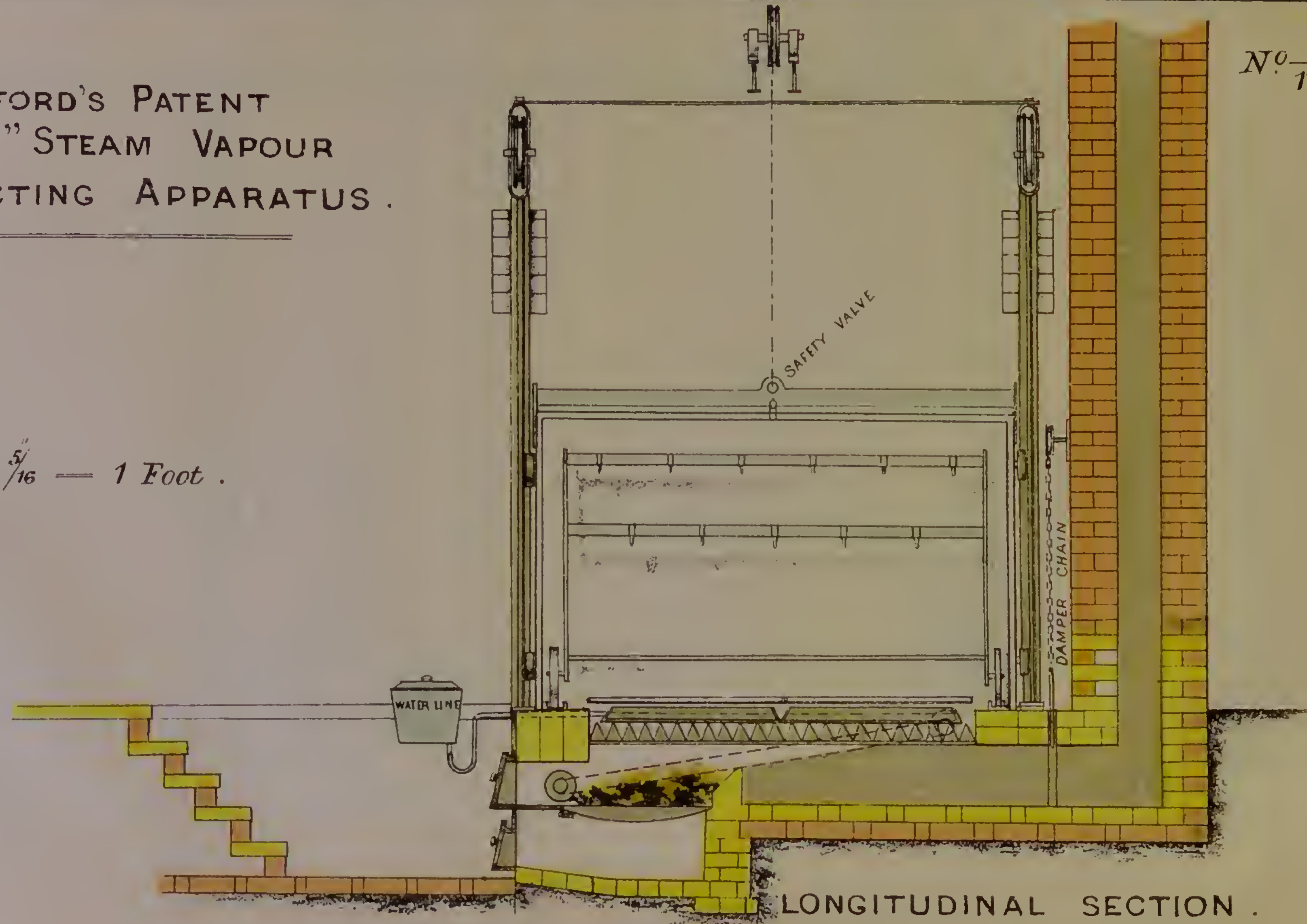
DANGERFIELD. LITH 22 BEDFORD ST COVENT GARDEN 10195.3/85

Nº 2. To face page 56

Bradford's Patent "Safety" Steam Vapour Disinfecting Apparatus.

Nº $\frac{1}{1756}$

Scale $\frac{5''}{16}$ — 1 Foot.



LONGITUDINAL SECTION.

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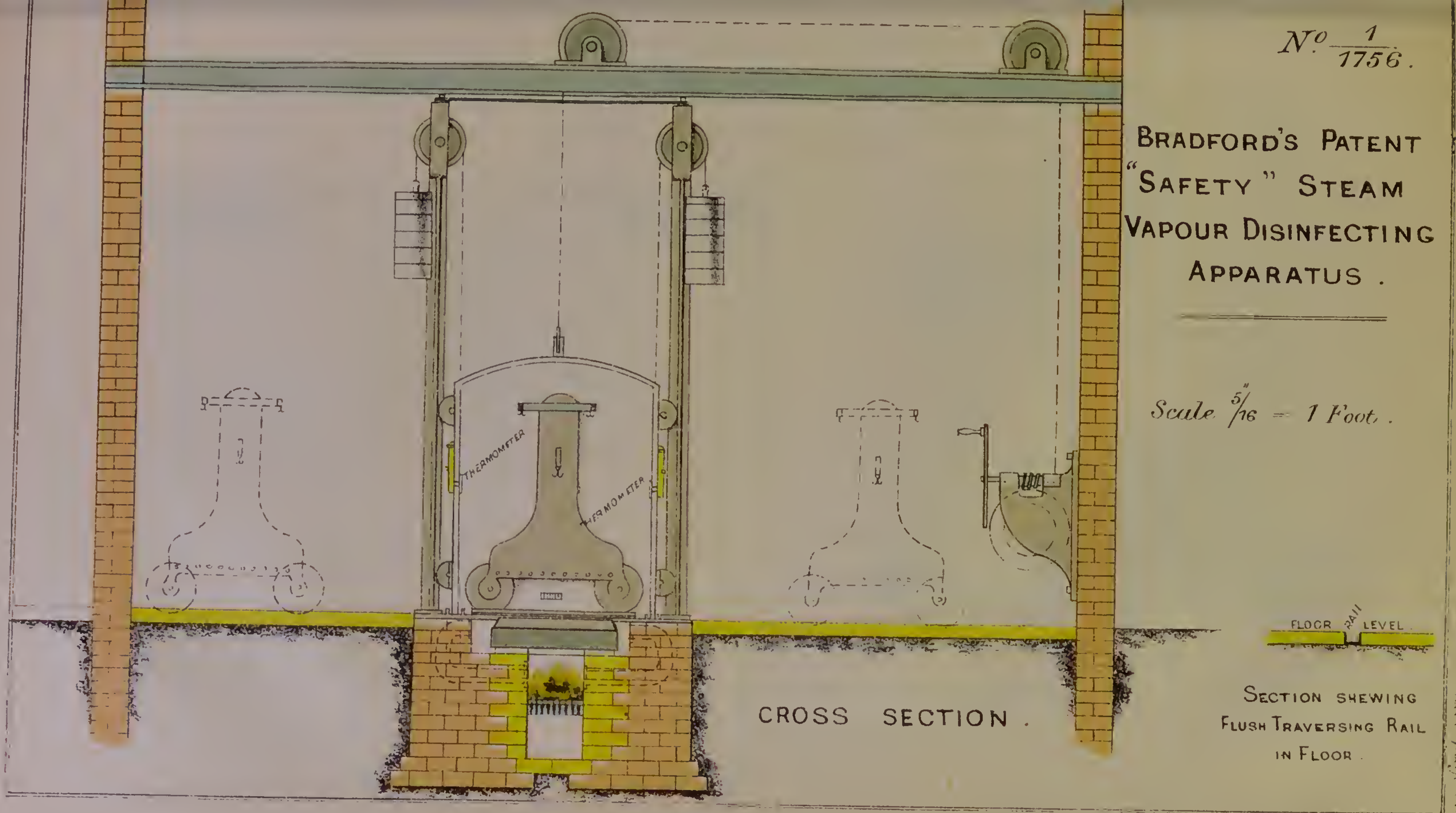
Nº 3. To face page 56



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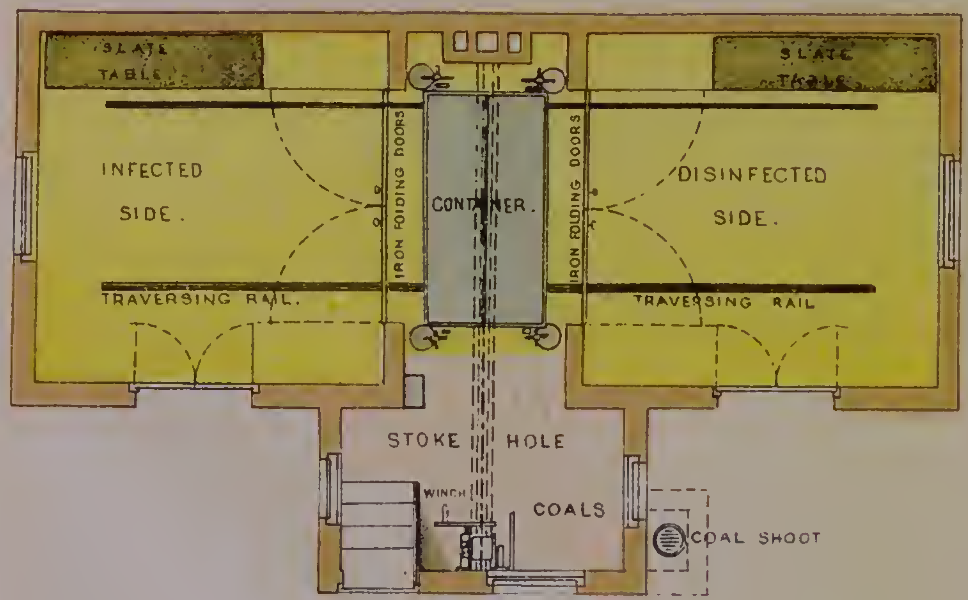
Bradford's Patent "Safety" Steam Vapour Disinfecting Closet.



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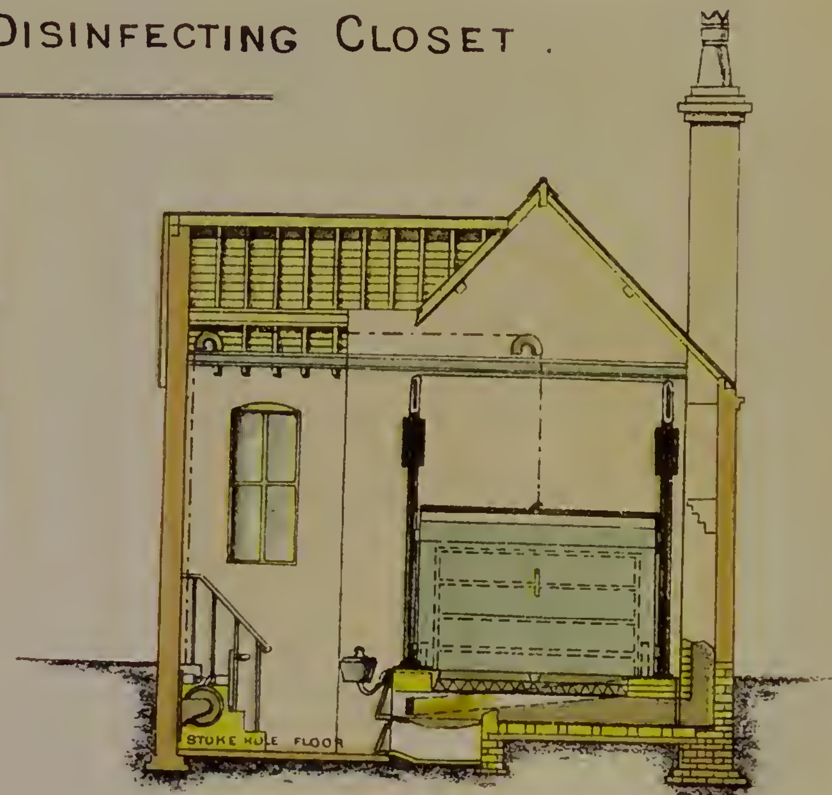

SECTION A. B.

Scale, 8 Feet = 1 Inch.

Nº 4. To face page 56.

Dangerfield, Lith. 22, Bedford St. Covent Garden 10195. 10195.3/86

A flock pillow, weighing $3\frac{3}{4}$ lbs. and containing a registered thermometer, was placed on the rack at the bottom. Six other thermometers (one with wet bulb) were placed in the chamber; the evaporating dishes were filled with hot water, and the container was closed at 4.50.

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The readings of the pyrometer and fixed thermometers were as follows:—

Time.	Pyrometer.	Thermometers.	
4.50	150°	Columns not in sight.	
5.10	250°	195°	197°
5.15	260°	204°	208°
5.20	265°	208°	213°
5.25	270°	211°	218°
5.30	280°	213°	222°
5.40	283°	223°	233°
5.45	284°	227°	236°

At 5.50, the container having been opened, the thermometers were found to mark:—

1. Rack on bottom by pillow (as 1 in Experiment 1) - 268°
2. Centre, mid-height (dry bulb) - - - 278°
3. Ditto (wet bulb) (as 2 and 3 in Experiment 1). - - - 212°
4. Level of top bars - - - - - - 272°*
5. Mid-length, bottom, at side, beyond asbestos - 298°
6. At far end, on bottom, beyond asbestos - - 270°
7. In pillow - - - - - - - 252°

This experiment shows that the pyrometer is more sensitive, and affords a more correct indication of the actual temperature of the chamber than the fixed thermometers.

It also shows that the use of the evaporating dishes has a marked effect in equalising the temperature in the chamber, heat being abstracted by evaporation from the hottest part and conveyed in the latent form to other parts. The moistness of the air is shown by the comparatively small difference (66° at 278°) between the readings of the wet and dry bulb thermometers, and this moistness appears to favour the penetration of the heat.

Another and very different form of apparatus by the same makers has been in use for several years in the Leamington Urban District; it stands in the Corporation yard under a railway arch.

Experiments with different form of apparatus at Leamington.

It consists of a chamber measuring externally 9 feet in frontage, 6 feet from front to back, and 7 feet high. The walls are of iron, cased externally with wood, except near the furnace. The furnace door is in front on the left; above it is a small door through which baskets containing articles to be disinfected can be placed in the hottest part of the chamber. Above this door is a pyrometer, actuated by a brass rod in an iron tube which extends across the interior of the chamber, about a foot below the roof. The furnace is an oblong iron box in the interior of the chamber, the flue ascending in the left-hand back corner. Above the furnace are two horizontal iron plates, one above another, and some distance apart, to intercept radiation.

Access to the chamber is obtained by a door in front on the right side. In the centre of the clear space is a strong upright iron spindle, furnished with horizontal movable branches which can be set at any

* This thermometer was nearest in position to the pyrometer, but it had a brass case which may have prevented its attaining a high temperature so quickly as the others, of which the bulbs were bare.

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angle. This spindle, together with the clothes, &c., hung on its arms, can be made to revolve by turning a handle on the outside, so that all the articles may in turn be exposed to an equal degree of heat.

There is an outlet flue with a revolving cowl in the roof of the chamber, and two inlets in the small door; there is also a communication, by opening which the air of the chamber can be drawn through the fire.

The inspector of nuisances states that the apparatus is usually worked at 250°, as shown by the pyrometer, and that with care clothing is not scorched. It is necessary, however, to place a screen to shade it from the radiation from the furnace, which gets red hot, and clothes are rarely placed in the baskets over the furnace.

Experiment 1.

On March 26th, 1885, the furnace had been lighted at 7.30 a.m.; at 9.50 the pyrometer stood at 240°.

Five thermometers were inserted, and the door was closed at 10.5. The pyrometer fell to 180°, but at 10.30 it had risen again to 260°.

The thermometers registered as follows :—

1.	At bottom of basket, over furnace	- - -	299°
2.	Slung on pyrometer rod	- - - -	280°
3.	Suspended on arm, in centre of chamber	- -	263°
4.	Ditto	at side farthest from fire, mid-height	260°
5.	Ditto	ditto 1 foot above floor	217°

Experiment 2.

Thermometers having again been introduced, the door was closed at 10.55. The pyrometer had fallen to 190°; at 11.15 a.m. it stood at 260°.

The thermometers then read :—

1.	In centre of chamber (dry bulb)	- -	260°
2.	Ditto (wet bulb)	- -	118°
3.	Over No. 1, close to roof	- - -	280°
4.	Under No. 1, 1 foot above bottom	- -	235°
5.	One foot from upright flue	- - -	300°

These experiments show that there is considerable variation in temperature in different parts of the chamber, but that the pyrometer indicates correctly the temperature in the central parts of the chamber. The reading of the pyrometer was lower than that of a thermometer hung beside it, but the explanation of this may be that a thermometer records only the temperature in the immediate neighbourhood of the bulb, whereas the pyrometer takes, as it were, the average temperature of the linear space through which the rod extends.

Taylor's disinfecting closet.

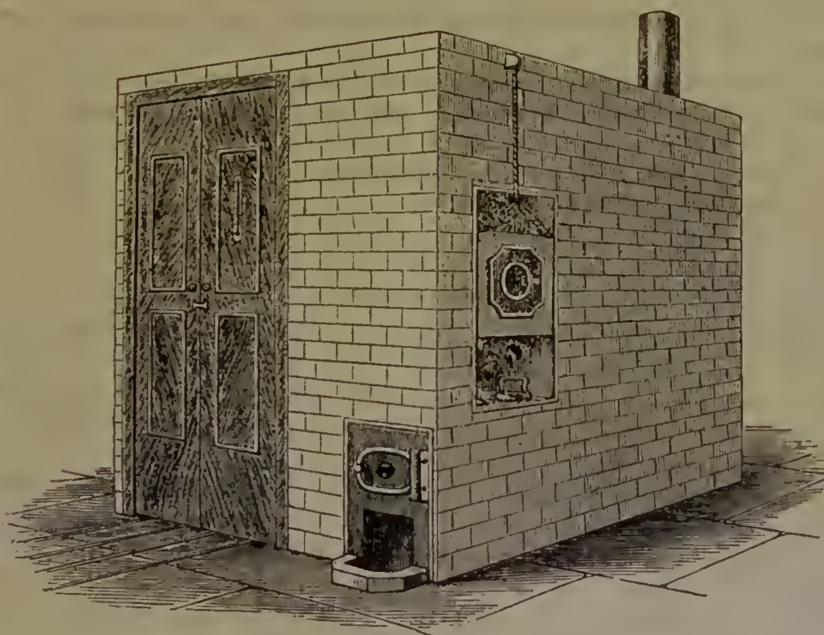
Taylor's Disinfecting Closet.

(Makers, Messrs. Thomas and Taylor, Stockport.)

This apparatus, which is in use at the Union Workhouse at Stockport, is a modification of the drying closet made by Messrs. Thomas and Taylor for laundry purposes; the modification which gives it its chief interest in the present connexion being the introduction into the chamber of steam by a pipe from a boiler outside. The closet is a brick-built chamber 7 feet long and broad, and about 7 feet high. Of the front

one half, the left, is occupied by wooden doors, through which the interior is entered; in the other half, which is of brick, are situated the furnace door, and above this a window (not shown in the woodcut) through which a thermometer hung in the interior of the chamber can be read.

On Disinfection by Heat; by Dr. Parsons.



The interior of the chamber is divided into two compartments by a brick wall, which, however, does not reach to the roof nor to the back, and is perforated with holes. In the right compartment is the body of the furnace, which is horizontal and made of corrugated cast iron, with a chimney at the far end. There is a sliding door at the side of the chamber through which, if desired, sulphur can be placed on the roof of the furnace. The left compartment contains two iron horses which slide in and out on rails in the floor.

At the back of the chamber is a pipe communicating with a boiler used for other purposes; through this pipe steam can be blown into the chamber.

There is an opening, closed by a slide valve, by opening which air from the chamber can be made to pass through the furnace. There is no damper or other contrivance for regulating the heat.

It is stated that the ordinary temperature of working, as shown by the thermometer hung against the window, is 180° to 240°. If the latter temperature be exceeded, articles on the top rail of the horse are liable to be scorched. Sulphur is rarely used. About 60 to 75 lbs. of coke are consumed each time of using, exclusive of the fuel used for heating the boiler.

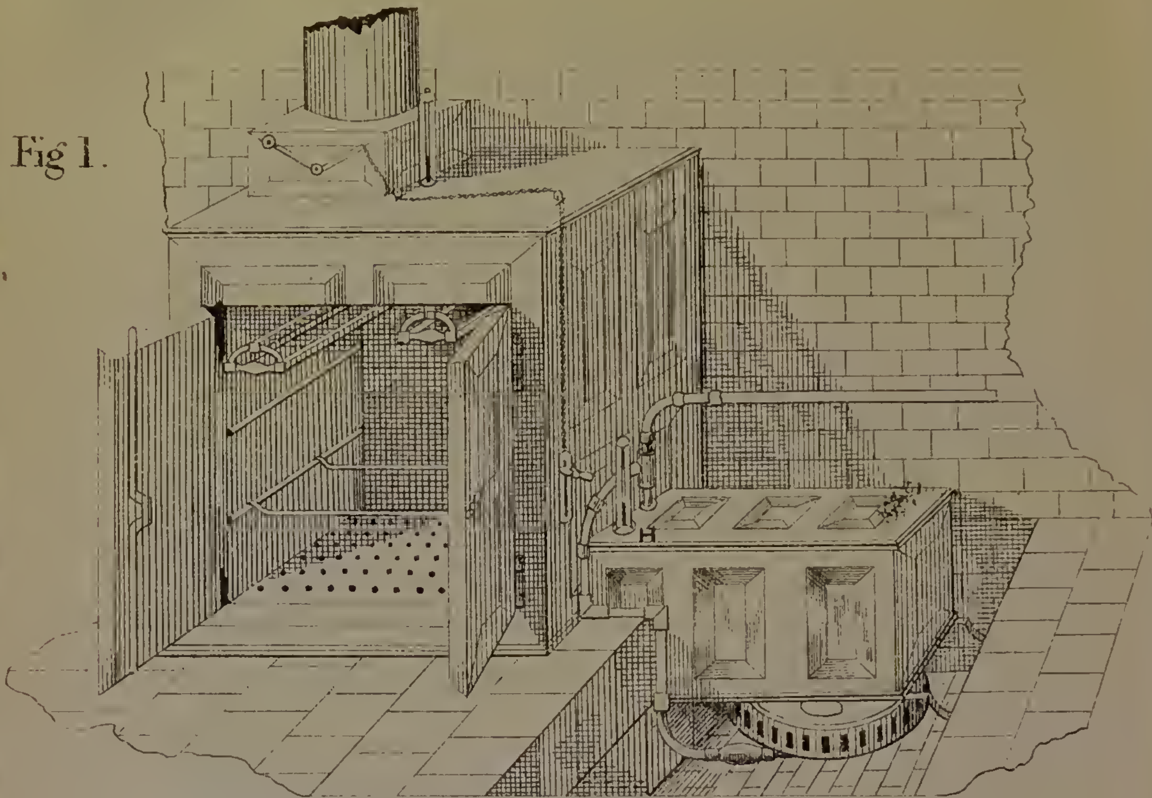
Experiments.

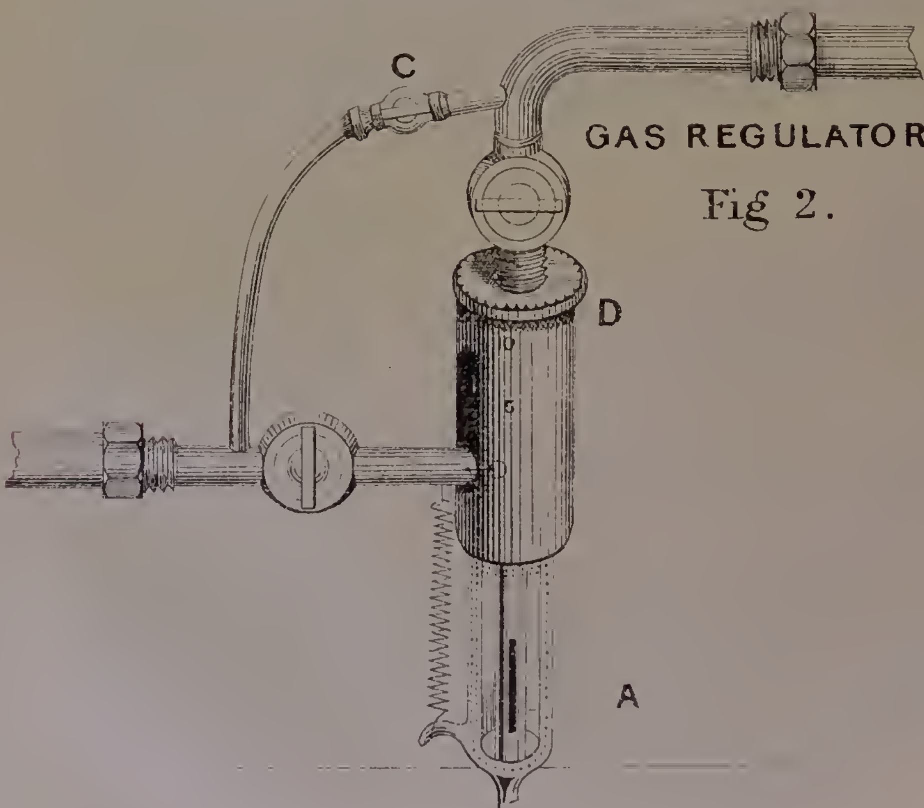
Experiments.

On April 16th, 1885, the stove had been lighted at 6 a.m. At 11 a.m. the fixed thermometer (that hung by the window) stood at 298°.

I. Five registering thermometers were placed in different positions on the horses, and the door was closed at 11.10; the fixed thermometer stood at 200°; at 11.40 it had risen to 267°. The thermometers inside were found to read as follows:—

Fig 1.





GAS REGULATOR.

Fig 2.

1. On top rails - - - - - 310°
2. On bottom rail - - - - - 226°
3. Hung by pillow - - - - 295°
4. Ditto (wet bulb) - - - - 192°
5. Inside pillow - - - - - 162°

On Disinfection by Heat; by Dr. Parsons.

The pillow had lost in weight about as much as the previous one; it was not scorched, but certain stains on it had become more evident.

During the experiment there was of course no pressure in the chamber above that of the atmosphere, and steam issued from chinks in the door, &c. At the same time, however, the considerable difference between the wet and dry bulb thermometers, and the loss of weight of the pillow, show that the amount of watery vapour in the atmosphere of the chamber was far below saturation.

It seems, however, to be proved that the admission of the steam materially aided the penetration of heat, for the temperature of the chamber, the duration of exposure, and other circumstances being as nearly similar as it was practicable to make them, the temperature attained in the interior of the pillow was 40° higher in the experiment with steam than in that without it.

It is to be remarked that when steam is used in addition to the heat generated in the furnace of the apparatus, a large quantity of heat generated in another furnace is conveyed into it, mostly in the latent form. There being, therefore, more heat employed, it is to be expected that a greater effect should be attained.

The pillows used on this occasion, it is to be noted, were thicker and heavier than those ordinarily employed: hence the results are not comparable with those obtained with other forms of apparatus.

2. *Apparatus in which heated air mingled with the products of combustion passes through the chamber.*

THE NOTTINGHAM SELF-REGULATING DISINFECTING APPARATUS.

(Makers, Messrs. GODDARD and MASSEY, Nottingham.)

Dr. Ransom's self-regulating disinfecting apparatus.

This well-known apparatus, the invention of Dr. W. H. Ransom, F.R.S., of Nottingham, is fully described and figured in Dr. Thorne's "Report on the Use and Influence of Hospitals for Infectious Diseases," pp. 210–214, to which I may refer for further details. It consists of a cubical iron chamber cased in wood with an intervening layer of felt, access to the interior being obtained by double doors. As manufactured for municipal disinfecting stations the chamber has doors on opposite sides and is placed in the partition wall which divides the establishment into two sides—an "infected" and a "clean" side, infected articles being carried into the apparatus on one side and removed when disinfected on the other.

The furnace is placed at the side of the chamber and on a lower level. It consists of a ring of atmospheric gas burners enclosed in an iron tube. The heated air containing the products of combustion passes along a horizontal flue and enters the chamber at the bottom, which is perforated by a number of holes for its equable distribution. In the horizontal flue are fixed the bulbs of a thermometer (H) and of a self-acting mercurial regulator. Through the latter the gas supply to the burners can be made to pass, and it is so constructed that as the temperature of the apparatus rises the mercury expanding encroaches upon a slit (A) through which the gas passes and thus gradually cuts off the supply. At the top of the chamber there is an outlet flue controlled by a valve and furnished with a thermometer (E). In connexion with the outlet is an arrangement designed for the extinction of fire: when the temperature

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at the outlet exceeds 300° a link of fusible metal melts, closing a damper and shutting off the supply of gas. The chamber is fitted with bars and hooks for suspending articles of clothing, &c.

When the stove is first lighted the gas is admitted to the burners direct through a short-circuit pipe (C) without passing through the regulator, but when the mercury in the latter has risen high enough to reach the slit, this pipe is closed by a tap so as to compel the gas to pass through the regulator. The regulator is furnished with an adjusting screw (D), so that it can be set to work at a higher or lower temperature as required.

Experiments at London Fever Hospital.

The following experiments were made with the apparatus at the London Fever Hospital, Islington:—

On July 4th, 1884, the apparatus was lighted at 6 a.m. after one day's disuse. At 11 a.m., the temperature of the air being 78°, the inlet thermometer stood at 255°, the outlet thermometer had not risen sufficiently high to be read. Four registering thermometers were placed in different positions in the chamber, which was then closed.

At 2 p.m. the outlet thermometer stood at 225°; 200 feet of gas had been burnt, or 67 feet per hour.

The chamber was opened and the thermometers inside were found to read as follows:—

1. On rack just above bottom, midway between centre of floor and side - - - -	211°
2. At mid-height and mid-breadth close to back wall - - - - - -	225°
3. On bars near top of chamber, at side - -	230°
4. Suspended in centre of chamber - - -	225°

Ten minutes after the opening of the chamber and taking out the thermometers, the outlet thermometer stood at 220°.

It was found that there was an accumulation of naphthalene in the gas pipes which prevented the full pressure of gas from being obtained.

On July 7th the gas pipes had been cleared and the apparatus had been in use since the afternoon of the 5th.

At 11 a.m. the inlet thermometer stood at 260° the outlet thermometer at 250°.

Four registering thermometers were placed in the same positions as on the previous occasion, and another one was pushed into the centre of a flock pillow weighing 3 lbs., which was placed on the bars at the bottom of the chamber.

At 4.30 p.m. the inlet thermometer stood at 263°, the outlet one at 250°. 380 cubic feet of gas had been burnt, or 69 cubic feet per hour.

The thermometers were found to register as follows:—

No. 1 - - -	247°
„ 2 - - -	252°
„ 3 - - -	256°
„ 4 - - -	252°

The thermometer in the pillow registered 227°; the pillow had lost 2 ozs. in weight.

Dr. Hopwood, resident medical officer, informs me that the apparatus is usually worked at a temperature, as shown by the fixed thermometers, of 250°–255° at the inlet, and 233°–236° at the outlet.

The usual practice is to light the gas at 6 p.m., by 9 to 10 p.m. the inlet has risen to 250°; the clothes are then placed in the chamber, and the automatic regulator being in action the apparatus is left till 6 next morning, when the clothes are taken out after nine hours exposure. They have occasionally, but rarely, been found to be scorched.

Dr. Hopwood states that he has never known scarlet fever conveyed by clothes which had been disinfected by a dry heat of 245°, or had

been washed in boiling water. He finds it necessary that the clothes should be spread out. He has not succeeded in getting a temperature above 180° or 190° in the middle of a thick bundle of clothes. He does not trust to hot air to penetrate a feather bed or hair mattress; such articles are unmade and purified by steam.

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Experiments at Aston.

Another apparatus of the kind was seen at the yard of the Aston Manor Local Board. This measures internally 5 feet by 6 feet, and 6 feet high; it opens at either end, and is placed in the partition wall between two rooms, which are approached separately from the outer air. The doors at either end are double, the inner doors, which are in two leaves, being of iron, the outer of wood lined with felt.

At the time of my visit (March 20th, 1885) the apparatus had been in use all night, a flock mattress having been in 10 hours.

A thermometer hung	in centre of chamber	registered	254°.
Ditto	placed on mattress	ditto	247°.
Ditto	in interior of mattress	ditto	220°.

It was stated that it took five to six hours to get up the necessary heat, and that the average time of exposure of articles was five and a half to six hours. Beds are disinfected by day in order that they may be returned to the owners by night; in busy times a second batch is stoved at night. No complaint of injury to goods has been made except in one case, in which the damage is believed to have arisen, not from scorching, but from staining, the ticking of the bed being wet with urine when placed in the stove.

The following experiment was made :—

Five registering thermometers were inserted and the doors were closed at 10.5 :—

At 10.5	the inlet	thermometer stood at	260°,	the outlet at	204°.
At 10.30	ditto	ditto	277°,	ditto	224°.

The thermometers inside read as follows :—

1.	In centre of chamber,	on bars near top	247°
2.	Ditto	suspended at mid-height	237°
3.	Ditto	on bars at bottom	251°
4.	Suspended close to side		238°
5.	Suspended close to door		233°

If the apparatus had been kept closed longer a more equable distribution of heat would probably have been recorded.

The great merits of this apparatus are the even distribution of heat—in the second experiment at the London Fever Hospital, when the gas was in proper order, the temperature in different parts of the chamber did not vary more than 9°—and the accuracy with which the temperature can be ascertained and can be adjusted and kept constant without supervision. Hence it may be used for the disinfection of such articles as will bear a temperature of 250° with little risk of injury. From Dr. Thorne's Report it appears that in the large experience of its use gained at Nottingham, Birmingham, Warrington, and Wigan, in very few instances have articles been injured, and then it has been from avoidable causes, such as leaving lucifer matches in a pocket, or wax ornaments on a silk dress; or putting articles in when damp.*

The chief drawback to its use appears to be the long time which it takes, first, to raise the chamber to the required temperature, and second,

* I do not think that exposing articles, such as blankets and bedding, to heat when damp, would have any injurious effect, provided that the dampness were only clean water. If, however, they were damp with urine or other impure liquid, the heat would have the effect of leaving a permanent stain, as spoken of in a former part of this report.

to accomplish the penetration of heat into bulky non-conducting articles. This would be a serious objection if constant supervision were required, but it is greatly diminished by the self-regulating action. The clothes may be put in in the evening, left unwatched through the night, and taken out in the morning.

At the same time this slowness of action must diminish the working power of the apparatus to a serious extent, especially where large quantities of articles have to be dealt with.

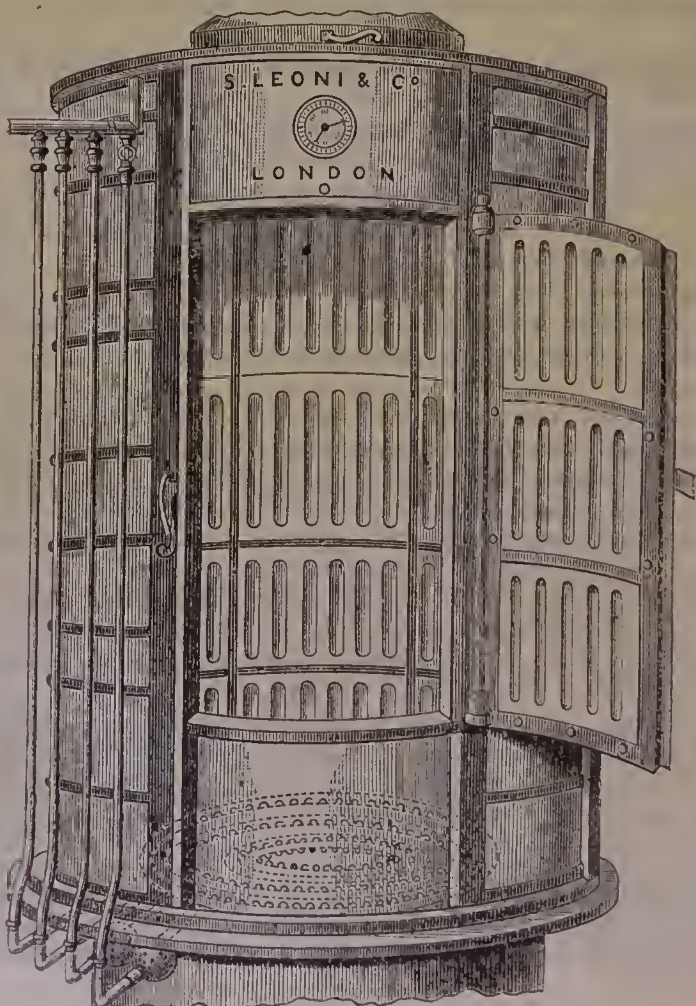
Another inconvenience is that the gas flame is liable to "catch back," especially if the doors to the chamber be suddenly opened or shut; *i.e.*, the gas burns before instead of after its admixture with air, with the result that little heat enters the chamber, but that the gas pipes get strongly heated. The occurrence of this accident is indicated by a slight explosion, and if it be found to have taken place the gas must be extinguished and re-lighted.

Leoni's Patent Disinfector.

(Makers, Leoni & Co., London.)

This apparatus was seen at the disinfecting station of the Limehouse Board of Works, where two of the kind have been in use for some years.

The apparatus consists of a cylinder built of tiles set in an iron frame, and in shape and size somewhat resembling a diving bell. The internal diameter is 4 feet 8 inches, and the height 9 feet, of which about 6 feet are above the level of the floor.



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In front there is a door by which access to the interior is obtained. The door is not of the full height of the chamber, for the lower edge is a little above the level of the floor in order to allow the door to open; nor does the door reach to the top of the chamber. Three feet below the floor level are rings of atmospheric gas burners, differing in detail in the two apparatus, but in both so arranged that one or more rings can be used at a time.

At the floor level is a grating on which articles to be disinfected can be placed and in the walls and roof of the chamber are arrangements of bars and hooks, on which other articles can be suspended. The articles to be disinfected are thus immediately over the gas flames, but at least 3 feet above them. In front above the door in one apparatus is a pyrometer, in the other a thermometer for indicating the degree of heat inside. In the centre of the roof is an outlet, which can be closed by a sliding valve. In practice this valve appears to be kept closed; in one of the chambers it was out of order and would not open. In this case the heated air and products of combustion were found to escape, partly by the side of the valve, which does not fit tight, partly through chinks in the walls of the chamber, and partly through the grating at the bottom provided for the supply of fresh air to the burners.

At Limehouse, where the disinfectors are placed under a railway arch in a crowded neighbourhood, the outlets are furnished with flues which pass into an iron chamber 3 feet high and 1 foot 6 inches in diameter, filled with lime, charcoal, and tow saturated with carbolic acid, with a view to purify the air issuing from the disinfectors. The lime and charcoal are said to be renewed once in two months, the carbolic acid once a week. The purifier seems to have been adopted mainly with the view of allaying the fears of the neighbours. But little air passes through it even when the outlet valve is open, and what does was found to be so highly charged with carbonic acid gas as to extinguish a burning match.

To prevent loss of heat by radiation the disinfectors are encased in brickwork, except in front. The disinfected articles have to be taken out by the same way that the infected ones are put in, thus apparently involving some risk of their being re-infected. It is stated, however, that articles brought for disinfection have usually been subjected to a preliminary fumigation with sulphurous acid in the houses from which they are removed. Mr. Rogers, the Medical Officer Health, states that he knows of instances in which disease had appeared to be contracted from infection retained in articles which had been exposed to disinfection.

Articles are sometimes injured by scorching; in such cases the Board of Works pay compensation.

The following experiments were made:—

(1.) In one of the disinfectors, which had been working for three hours, four thermometers were placed in different positions. In a quarter of an hour from closing the door the thermometer attached to the apparatus had risen from 180° F. to 260° F.

On opening the chamber the thermometers inside were found to register—

1. Close to the roof - - -	352° F.
2. On a grating between roof and floor, in centre - - - -	366° ,,
3. On same grating, at side - -	372° ,,
4. On grating at floor level, in centre -	372° ,,

A wet-bulb thermometer, hung between 1 and 2, registered 161° F., indicating a very small degree of humidity.

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(2.) A similar experiment was made with the other machine which had not been heated before the commencement of the experiment. The day, however, was a hot one, the temperature of the air being nearly 80° F. The burners being lighted, the pyrometer attached to the disinfector in half an hour indicated 200° F. The consumption of gas was found to be at the rate of about 140 cubic feet per hour. On opening the chamber the thermometers which had been placed in it indicated—

1.	Close to roof - - - -	306° F.
2.	On upper grating, in centre - -	312° ,,
3.	Ditto at side - -	308° ,,
4.	On floor grating - - -	324° ,,

The wet-bulb thermometer, hung between 1 and 2, registered 145° F.

These experiments show that the distribution of heat within the chamber is fairly uniform, varying not more than 20° F. in different parts of the chamber, but that the pyrometer or thermometer attached to the disinfector does not indicate the actual temperature of the interior by more than 100° F. This explains how it is that scorching is apt to take place Whether this discrepancy is due to causes inherent in the construction of the disinfector, or to defects of those two particular examples, I am unable to say.

(3.) A coarse feather pillow weighing $5\frac{1}{4}$ lbs., with a thermometer inside, was placed in the disinfector on the upper grating for half an hour (the time usually allowed for such an article), the pyrometer standing at 200°, equal to an actual temperature of 312° F. At the end of that time the calico pillow case was slightly scorched, and so weak that it would not sustain the weight of the pillow as it had done before. The thermometer in the interior registered only 140° F.

Mr. Rogers informs me that a thermometer in the centre of a flock bed reached 230° F. in $2\frac{1}{4}$ hours, the pyrometer standing at 260° F., which, however, as I have shown, would mean a temperature of over 360°.

Though differing from it in form and arrangement, Leoni's disinfector resembles Ransom's in principle, in that the articles to be disinfected are exposed to the hot air and products of combustion rising from the burners, and not merely to the radiation from heated surfaces. Leoni's disinfector appears to possess the advantage of economy in time and gas; it took only half an hour and about 70 cubic feet of gas to get up a temperature of over 300° F., whereas Ransom's took about four hours and nearly 280 cubic feet of gas to reach an internal temperature of between 250° and 260°. On the other hand, Ransom's disinfector has, in its mercurial gas regulator and fusible link arrangement for the extinction of fires, the advantage of automatic action, by which supervision is saved, and risk of injury to the articles undergoing disinfection is lessened.

Scott's Patent Disinfecting Apparatus.

Scott's patent disinfecting apparatus.

(Made by Maguire and Son, Dublin.)

This apparatus is made in both a fixed and a portable form, and can be heated either by gas or by coal.

When heated by gas it is now furnished with a self-acting regulator which controls the generation of heat by acting upon the supply of gas to the burners. When heated by coal, the heat, of course, cannot be regulated in this way, but there is an automatic ventilator which is opened by the expansion of a copper rod when the temperature reaches a certain point, and allows a current of air to pass through the apparatus.

Experiments at Portsmouth Municipal Hospital.

The first experiments to be described were made with the apparatus belonging to the corporation of Portsmouth, and erected at the

Infectious Hospital there. This apparatus is used for municipal sanitary purposes as well as for the use of the hospital.

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It consists of a brick-built oven 6 feet by 6 feet in internal dimensions and 7 feet high, with doors at either end. This is enclosed in a brick building in such a manner as to leave a passage on all sides between the oven and the outer wall. A partition wall, level with one end of the oven, divides this building into two distinct compartments, the larger for infected, and the smaller for disinfected articles.

The oven is heated by gas; it is provided with an automatic ventilator, but not with a self-acting gas regulator. The burners, which are of the luminous, not of the atmospheric, kind, are arranged in two square concentric rings, and are placed in the centre of the floor in a sheet-iron box, open around the sides above, but having a sheet-iron roof. The burners are supplied with air from the outside through two flues opening within the box. There is, in addition, a Bunsen gas tripod, upon which a boiler can be placed to supply steam if thought desirable; in practice, however, the same object is attained by placing a tin evaporating vessel on the iron roof over the burners.

There are separate taps for the two rings of burners, so that one or both rings can be used. Near the entrance door is a thermometer fixed in the wall, the bulb of which, enclosed in a perforated brass tube, projects 6 inches into the interior of the chamber in the corner by the door.

The doors, though only 3 inches thick, are very non-conducting; after six hours use they felt quite cold below, and scarcely warm above. In the door are two holes, double glazed, through which the gas jets can be seen. There are sliding hooks along the roof of the chamber, and two tiers of shelves on each side of tiles supported by iron bars. On these shelves wooden bars rest, on which articles to be disinfected can be placed.

The following experiments were made :—

Experiment 1.

Six registering thermometers having been placed in different positions in the stove, the gas was lighted and the door closed.

The consumption of gas, when fully on, was found to be at the rate of 200 cubic feet per hour.

The automatic ventilator, which is ordinarily kept fastened so as to prevent it from acting, was found to open when the fixed thermometer indicated about 180°, above which point the latter rose very slowly. The attendant stated that when the ventilator was free to act, it was with difficulty that the fixed thermometer was got up to 240°, the temperature considered necessary for disinfection. The ventilator was accordingly closed again.*

In an hour from lighting the gas the fixed thermometer indicated 240°; the door was then opened, and the thermometers inside were found to read :—

1. Close to roof, in centre of area - - -	314°
2. On top shelf, midway between two doors - -	305°
3. On lower shelf ditto ditto - -	338°
4. Middle of chamber, on bars resting on top shelf -	283°
5. Ditto ditto ditto lower shelf -	313°
Average - - -	310°
6. On lower shelf in corner by door - - -	242°

* It could not, of course, have been air-tight, or the gas-flames would have been extinguished by the exhaustion of the oxygen in the air of the chamber.

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This experiment shows that the fixed thermometer does not indicate the actual temperature in the central parts of the chamber; of the six thermometers only one, and that in a position nearly corresponding to the bulb of the fixed thermometer, registered nearly the same temperature; of the other five in the more central parts of the chamber, the average reading was 70°, and the highest nearly 100° above the fixed thermometer.

The chamber, when opened, was full of irritating empyreumatic vapour, produced by the charring of the wooden bars. Evidently 240°, as shown by the fixed thermometer, is too high a temperature at which to work.

Apparently, if the automatic ventilator were left free to act, a heat would be attained in the central parts of the chamber as high as it is necessary or safe to use.

Experiment 2.

A flock mattress, $2\frac{3}{4}$ inches thick, was laid flatwise across the centre of the chamber on bars resting on the upper shelves, and a registering thermometer was pushed into the centre.

A horse-hair mattress, 5 inches thick, with thermometer inside, was laid in similar fashion on bars resting on the lower shelves.

A feather pillow, weighing 3 lbs., containing a thermometer, was also laid upon the lower bars. A bare thermometer was laid beside it on the bars.

The oven door being closed, in 10 minutes the fixed thermometer had risen to 220°, at or near which point it was kept (varying between 210° and 236°) for four hours, the consumption of gas required to maintain this temperature being at the rate of about 90 cubic feet per hour.

During the progress of this experiment a wet and dry bulb arrangement of registering thermometers was suspended near the position of thermometer 2 in the previous experiment, and the readings were found as follows:—

	Quarter of an Hour's Exposure.	Half Hour's Exposure.
Fixed thermometer - -	224°	224°
Dry bulb - - -	285°	286°
Wet bulb - - -	135°	139°

The great difference between the two bulbs shows that in spite of the evaporation from the water in the tin pan, the air in the chamber is very dry.

At the end of $2\frac{1}{4}$ hours, the fixed thermometer having risen once in the interval for a short time to 236°, the pillow was taken out and the thermometer read:—

Thermometer in pillow - - -	137°
Ditto on bars beside it - -	344°

The thermometer was re-inserted and the pillow replaced as quickly as possible. The ticking of the pillow was found to have been scorched.

At the end of four hours the readings of the thermometers were:—

In flock mattress - - - -	194°
In hair mattress - - - -	138°
In pillow - - - - -	138°

The less penetration of heat into the hair than into the flock mattress was doubtless due to the greater thickness of the former. The feathers in the pillow were somewhat tightly packed, accounting for the

difficult penetration of the heat as compared with that in some other experiments.

It would appear from these experiments that, if the stove at Portsmouth is to be taken as a fair example, Scott's apparatus, though ingeniously contrived and well made, is not free from the defects common to so many forms of dry-heat apparatus, viz., the unequal diffusion of heat in different parts of the chamber, and the absence of any trustworthy guide to the temperature actually attained in the interior.

It seemed desirable to make further tests with another example of this apparatus, and I therefore made, with the permission of Surgeon-Major Ferguson, medical officer in charge, some experiments with the stove at the Herbert Hospital, Woolwich.

This stove is smaller than that at Portsmouth, being 5 feet square externally, and 6 feet high; it differs from it in being built of iron instead of brick. The hollow panels are filled with non-conducting substance, which is very effectual in preventing the transmission of heat to the outside. It has not the automatic ventilator, the outlets being closed by valves worked by hand. There is a self-acting gas regulator consisting of a pile of corrugated metal boxes like those of an aneroid barometer; this pile is fixed at one end by a screw, and the other end is furnished with a conical point projecting into a circular orifice, through which the gas passes. When expanded by heat, the pile elongates, and the conical point being thrust further into the orifice, diminishes the supply of gas. By turning a handle connected with the

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screw, the point can be made to advance or recede, and the regulator thus set to work at a higher or lower temperature. There is a by-pass with cock by which the gas can go to the burners without passing the regulator; this is directed to be kept open until the temperature has reached 250° or the point at which it is desired to work, and then almost but not quite closed. The thermo-regulator is fixed in the corner corresponding on the other side of the door to that in which the bulb of the fixed thermometer protrudes.

There is also an arrangement by which, if the temperature in the chamber should exceed a given point, a chain of fusible metal melts and the fall of a weight shuts off the supply of gas; this arrangement is not now in use. The arrangement of burners is slightly different in detail from that at Portsmouth, and the shelves are of latticed ironwork instead of tiles.

Articles submitted for disinfection are loosely piled in wooden baskets, and the directions state that these should be allowed to remain in the chamber an hour from the time at which the fixed thermometer indicates 250°.

The following experiments were made:—

Experiment 1.

The apparatus being cold (it had been used the previous day), six registering thermometers were placed in different positions, the gas was lighted, and the door closed.

It took 2½ hours for the temperature, as shown by the fixed thermometer, to reach 250°. The door was then opened, and the thermometers inside were found to read as follows:—

1.	On bottom shelf, mid-way between doors		-	280° F.
2.	On middle	ditto	ditto	-	298° „
3.	On top	ditto	ditto	-	303° „
4.	Suspended in centre, over burners		-	292° „
5.	Ditto	close to roof	-	296° „
6.	In corner, close to regulator		-	289° „

These results show a fairly equable distribution of heat in the parts of the chamber in which articles for disinfection are intended to be placed, but, as in the Portsmouth chamber, the fixed thermometer does not indicate the actual temperature of the interior.

Experiment 2.

A thermometer was inserted into a horse-hair pillow of ordinary dimensions which was placed in one of the wooden baskets ordinarily used here. Another thermometer was laid in the basket beside it, and the basket was placed on the middle shelf in the centre of the oven. In another basket two woollen rugs (used as coverlets for beds), loosely folded, were lightly laid one upon the other, this being the way in which such articles are commonly exposed in the stove. A thermometer was placed between the two rugs, and the basket was placed in the corresponding position to the first one on the other side of the stove. Another thermometer was placed close to the bulb of the fixed thermometer.

The fixed thermometer had fallen to 210°, and it was 50 minutes before it had risen again to 250°. The by-pass cock was then almost closed, and the temperature maintained for an hour. It was found that, the regulator being set at 250°, the fixed thermometer remained constant at that temperature when the by-pass was closed, not varying in

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the hour by more than a degree either way. At the end of the hour the experiment was terminated, and the results were found to be :—

Thermometer in basket, beside pillow	- -	276°
Ditto in pillow	- - -	149°
Ditto between rugs	- - -	138°
Ditto in corner by fixed thermometer		283°

This experiment, like others, shows that "stoving" as commonly practised, is not sufficient to ensure the penetration of an adequate degree of heat through articles to be disinfected. It confirms the previous one as to the failure of the fixed thermometer to indicate the heat of the interior. There is, however, a difference in this respect between the stoves at Woolwich and Portsmouth; in the latter a registering thermometer placed in a position corresponding to the bulb of the fixed thermometer, indicated about the same degree of heat as it —a less degree than in the centre of the chamber. In the former a thermometer placed near the bulb of the fixed thermometer indicated a higher degree of heat than it, nearly equal to that in the centre of the chamber. Hence at Woolwich, either the scale must be wrong or else the bulb of the thermometer is in some way screened from the heat. The iron tube, in which for protection it is placed, may not improbably carry away to the outside by conduction some of the heat which otherwise would reach the thermometer.

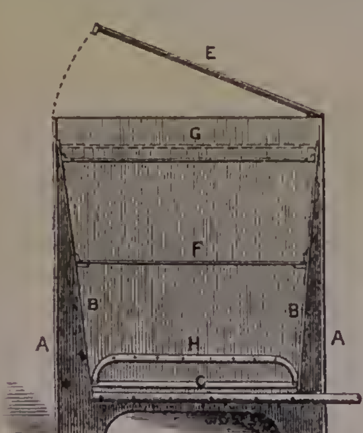
The articles placed in the stove did not exhibit any sign of injury, nor, I am informed, is scorching often found to take place, though a fire once occurred which was believed to have been caused by the ignition of matches accidentally left in the clothes. The articles to be disinfected are always placed in wooden baskets, and as far as possible from the gas furnace. I attribute the infrequency of scorching to the direct rays of radiant heat being intercepted by the baskets. It is found that articles coming in contact with metal are liable to be scorched.

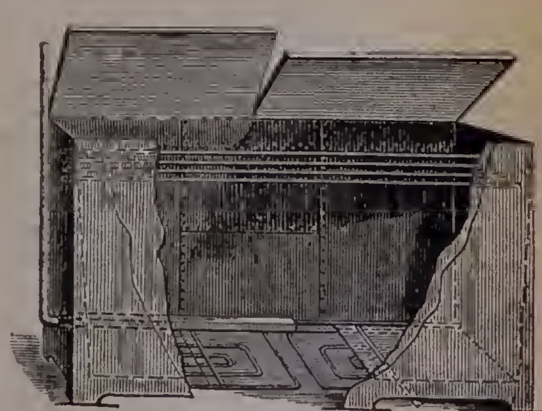
Jennings's disinfecting apparatus.

Jennings's Disinfecting Apparatus.

(Maker, Thomas Jennings, York Road, Lambeth.)

This is a chamber similar in general arrangement to Nelson's stove. The external dimensions of an example seen by me at the inventor's premises in Lambeth were 7 feet 9 inches by 3 feet 3 inches, and 4 feet high.





The chamber is made of iron plate $\frac{1}{8}$-inch thick. On the four sides the shell is double, containing a cavity 3 inches wide at the bottom diminishing to $\frac{3}{8}$-inch at the top. The bottom of the chamber is formed

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by a single iron plate. The chamber is closed above by a hinged lid in two pieces, which are counterpoised, or can be raised with a windlass. The sides and lid are coated externally with asbestos composition with a view to economize heat. Beneath the bottom and at a distance of $1\frac{1}{2}$ inches from it is a series of atmospheric burners containing 500 jets. The space between the inner and outer shells is open at the bottom and communicates above with the interior of the chamber by a double row of holes around the four sides. The interior of the chamber is connected with a flue at the side by an aperture opening in the centre of the bottom, and capable of being opened and shut from the outside by a sliding valve.

The heated air ascending from the burners impinges upon the bottom of the chamber, and ascending in the space between the two shells, enters the interior through the holes, and is drawn off by the flue. There are racks to prevent articles coming into contact with the heated sides and bottom, and rods and hooks for the suspension of articles to be disinfected.

There is a hole in the lid through which a thermometer can be inserted to test the temperature of the interior, but the apparatus is not provided with any self-acting means of regulating the heat.

The following experiment was made :

Six registering thermometers having been placed in different positions in the chamber, which was cold, the gas was lighted. In half an hour a thermometer inserted through the hole in the lid marked 252° F.; 80 cubic feet of gas having been burnt. The chamber was then opened, and the thermometers were found to read as follows:—

In centre of chamber.	At top - - - -	254° F.
	Midway between top and bottom -	249° "
	On bars near bottom - -	287° "
At one end of chamber.	At top - - - -	238° "
	Midway between top and bottom -	250° "
	On bars at bottom - - -	259° "

There was thus a difference of some 50° in temperature between different parts of the chamber; these, however, were extreme points, and in the more central parts the temperature was tolerably uniform.

This apparatus it will be seen is intermediate between those in which the heat is applied to the walls of the chamber and those in which the products of combustion pass into the interior. Having only recently been brought out, practical experience of its working is not yet available.

Disinfecting oven at Hôpital St. Antoine, Paris.

Disinfecting Oven at Hôpital St. Antoine, Paris.

(Constructed by Haillot, Paris.)

A drawing of this machine was exhibited in the International Health Exhibition. The oven is of brick with cavity walls, and wooden folding doors at either end. It is traversed by a set of rails on which runs a waggon, carrying the articles to be disinfected: another railway suspended from the roof bears a carriage with hooks for hanging articles on. The length of the chamber is about 8 feet, the breadth externally 6 feet, within 3 feet 6 inches; the height externally 7 feet 6 inches, within 6 feet 6 inches. The chamber is heated by a series of gas burners in a furnace below and at the side as in Ransom's stove: the burners are not atmospheric. A somewhat complicated arrangement of gas pipes was shown connected with a governor and meter, a short-circuiting arrangement and pressure gauges, but apparently without any automatic heat regulator. The hot air from the burners enters the cavity of the

wall, which is connected with the interior of the chamber by three openings near the top and three near the bottom. The cavity on the side opposite the furnace is connected with the exhaust flue, and communicates with the chamber by openings at the bottom only. The exhaust flue is prolonged into a chimney, and the draught can be regulated by a throttle valve. No thermometer was shown.

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3.—*Apparatus heated by Steam or Hot Water circulating in a Coil of Pipes.*

I have not seen any apparatus of this class. The following are descriptions of several apparatus in use (or proposed to be used) on the Continent where the principle seems in more favour among makers of such appliances than it is in this country. It will be noticed that in several a steam jet is introduced into the chamber, but the supply of steam is so small relatively to the size of the chamber (which moreover is not air-tight) that the apparatus can only be classed as employing hot moist air in a manner similar to Taylor's, before described.

Disinfecting stove of Geneste, Herscher, & Cie.

A disinfecting stove made by Geneste, Herscher, et Cie, of Paris, was represented in the International Health Exhibition by a small wooden model, which was labelled "Disposition pour l'emploi successif de l'air "sec et de la vapeur directe. Type transportable: échelle de 0m. 20 par "mètre." Multiplying by 5 the dimensions of the model, those of the full-sized apparatus would be externally about—

Length (front to back), 7 feet 6 inches.
Breadth, 5 feet.
Height, 7 feet 6 inches.

The internal space available for the reception of articles to be disinfected would measure—

Length, 7 feet.
Breadth, 3 feet 6 inches.
Height (rails to roof), 6 feet 8 inches.

Although labelled portable, it is apparently a fixture; but in the makers' prospectus the chamber is described as constructed of panels of cast iron which can be taken apart and fitted together again. These panels are hollow and are filled with pumice stone to diminish loss of heat.

Immediately within the walls is a double spiral coil of hot-water pipe which lines the chamber at the sides and the floor, but not at the roof nor the ends.

At each side interior to the coil is an iron screen, the object of which is to cut off direct radiation from the hot-water pipes, and to cause the current of hot air in the chamber proper to pass downwards and not upwards, with a view to secure the more equal distribution of heat. The bottom of the chamber is traversed from end to end by a pair of iron rails lying above the hot-water coil. Along these rails a waggon, with racks for bedding, &c., slides in and out. There are doors at either end of the chamber, so that the waggon can be pushed in at one end and out at the other. The doors are described in the prospectus as fitting against a seating of asbestos rope, but it is difficult to see how they can fit air tight over the grooves in the rails.

The chamber is heated by a furnace outside, in which coils of hot-water pipe are spirally arranged. There is also a boiler, heated by a separate fire, for the supply of steam, which enters by a pipe apparently at the upper and back part of the chamber. The pipe as shown is very small for the supply of steam to so large a chamber. There could be no pressure, and apparently a damping of the air is all that is aimed at.

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An outlet flue, closed by a valve, is shown leading from the upper part of the chamber into the chimney. At the side farthest from the furnace is an opening for inspection, closed by a sliding door, above which is a thermometer; this, being close to the hot-water pipes, could not be expected to afford a trustworthy indication of the temperature in the interior.

In Vallin's Treatise on Disinfection (Paris, 1883), p. 454 *et seq.*, a somewhat similar stove designed by M. Herscher, is described, but is not spoken of as having been actually constructed. The degree of heat which it is considered advisable should not be exceeded is 110° C.(= 230° F.), and M. Vallin considers that an exposure of four hours would be sufficient to secure a temperature of 100° C.(=212° F.) in the centre of a mattress.

Disinfecting stove at Hôpital St. Louis, Paris.

There was also in the International Health Exhibition a drawing of the disinfecting stove at the Hôpital St. Louis* at Paris; this was constructed by Haillot & Cie., Paris. The machine is similar in general arrangement to Herscher's, but the heating pipes are larger, and are beset with closely arranged flanges and gills for increasing the radiating surface. They are placed in a single row round the sides, and in a double row at the bottom. The stove is of brick, with double walls, enclosing a closed cavity. Its external dimensions are: length, 10 feet 6 inches; breadth, 7 feet 4 inches; height, 7 feet 4 inches above the ground and 1 foot 5 inches beneath it. Those of the internal clear space are: length, 8 feet; breadth, 3 feet 6 inches; height, 6 feet 6 inches. There are wooden doors at either end. There is an inlet for ventilation in the floor and an outlet in the roof. The steam circulates in closed pipes and does not escape into the chamber.

Apparatus at Moabit Hospital Berlin.

The "new" disinfecting apparatus at the Moabit Hospital near Berlin, in which Drs. Koch and Wolffhügel's experiments on disinfection by hot air were made, is similar in principle to those of M. Herscher just described. It is heated by high-pressure steam in a closed coil of copper pipe.

The older apparatus was a cast-iron cylinder closed by a lid; it was sunk in the ground to prevent loss of heat by radiation, and heated by a coil of pipe.

Of Dr. Esse.

An earlier apparatus contrived by Dr. Esse, of Berlin (Vallin, *loc. cit.*, p. 460), consisted of a double cylinder of iron heated by steam admitted into the space between the two cylinders. This, indeed, is similar to the arrangement employed by Dr. Henry in his early researches before alluded to.

Of Oscar Schimmel & Co.

Another apparatus on the same principle is made by Messrs. Oscar Schimmel & Co., of Chemnitz. This is heated by a double series of flanged pipes in which steam circulates, and is also provided with another pipe by which steam can be admitted into the interior of the chamber. In using it the articles are exposed first to dry heat, then to a current of steam, and then again to dry heat to evaporate any moisture left by the steam.

4.—*Apparatus in which a Hot Blast is employed.*

Seagrave's hot wind apparatus.

SEAGRAVE AND BEVINGTON'S PATENT HOT-WIND APPARATUS.

This machine, which was exhibited in action at the International Health Exhibition, is designed primarily for drying moist substances in

* M. Vallin, however, in his work, describes and figures as existing at the Hôpital St. Louis a disinfecting stove quite different from the above; it is heated by gas, and furnished with a thermo-regulator, by which it is stated the temperature can be maintained constant within 2° C.

bulk, such as hops, wool, peat, &c. It is described, however, by the inventor as being available for disinfection purposes, and as it embodies a principle, viz., the hot blast, so far as I am aware, not previously employed for disinfection, and perhaps capable of further development, I think it well to mention it here. The machine will, however, need considerable modification to adapt it for use as a disinfector, except perhaps in a few special cases. On Disinfection by Heat; by Dr. Parsons.

The machine, as exhibited, consisted of three parts: 1st, a blower (Stewart's patent high-pressure blower), worked by steam, in which a rapidly intermitting current of air is produced by two blades revolving at varying velocities within a cylinder; 2nd, a furnace which is traversed by a number of tubes through which the air from the blower passes, thus exposing the air to a large heating surface; 3rd, a floor on which to place the materials to be subjected to the current of hot air. This floor is a large rectangular sieve of wire-netting with upright wooden sides, standing over a funnel-shaped cavity, in the bottom of which the pipe conveying the hot air terminates. By opening a valve the hot blast can be diverted from the floor through an escape pipe into the open air.

The apparatus can, it is stated, be made in a portable form if necessary.

The following experiments were made. A registering thermometer was wrapped in 4 yards of cotton wool making a roll 14 inches by 6 inches, and placed on the floor. Three other thermometers were placed naked in different parts of the floor, and the blast, the temperature of which, as ascertained by a thermometer held in the escape pipe, was 219° F., was turned on. Experiments.

At the end of five minutes the thermometers read as follows:—

1. In centre of floor	- -	200°
2. At side of floor	- -	186°
3. In corner of floor	- -	182°

The thermometer in the cotton wool stood only at 86°.

In another experiment a thermometer in the centre of a bag of cotton waste placed on the floor, after an hour and a half's exposure stood only at 102° F., the temperature of the blast being 224°.

The duration of exposure in these experiments, though short in comparison with the time found necessary for penetration of heat in a hot-air chamber, would have been sufficient for penetration by steam.

It was evident that the capabilities of the machine in forcing heat through a non-conducting material could only be tested properly upon some material which completely filled the floor, so that the blast was compelled to traverse it, otherwise the hot air merely came up by the side of the object, and did not pass through it.

An attempt was made to test the penetrative power of the hot blast by introducing a roll of cotton wool enclosing a thermometer into the escape pipe through the valve, which was then partly closed behind it, so as to retain it in place, but it was found that the puffing action of the blower not only jerked the index of the thermometer out of place, but forced the thermometer itself bodily through the wool, so that it was found lying loose in the pipe.

I had arranged on another day to make some experiments with rags and flock spread out upon the floor, but unfortunately on my arrival I found that the furnace had got out of repair, and it was not in order again before the Exhibition closed.

It seems to me possible that this machine might be made available for the disinfection of loose materials, such as rags or mohair, which

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could be spread abroad over the floor in a layer of uniform thickness, but as at present arranged it would not do for made-up articles, as of clothing or bedding, for if these did not completely cover the floor the hot air would come up by the side of, and not through them. It would be necessary to have some means of regulating the temperature of the blast; and it would also be necessary to contrive some means to prevent infected dust being blown into the air, and thus infection disseminated around. Possibly it might be found practicable to box in the floor and carry the air which had passed through it into the furnace.

In the "Sanitary Record" for December 15th, 1880, p. 208, a figure is given of an apparatus devised by Messrs. Stobbs & Seagrave for disinfecting fabrics by forcing through them currents of heated air or superheated steam. The apparatus as shown is portable, running on wheels. I learn, however, from Mr. Seagrave that no such machine has as yet been actually constructed.

(b.)—*Steam Apparatus.*

Disinfection by a current of steam.

5.—*Employing a Current of Steam.*

As I have said, I have not seen an apparatus on this principle, though I understand that it is in use in some trade establishments.

Of bales of rags.

A system of rag disinfection by superheated steam mentioned by the "Laundry News," May 1885, and stated by the editor to be in use in America, may be conveniently spoken of in this place. It is effected in an air-tight box, into which each bale of rags is drawn by means of five screws which at the same time make five perforations from end to end of the bale. Superheated steam is injected through the screws, which are hollow and perforated with holes permitting jets of steam to penetrate through the rags in every direction. The steam employed is raised to 330° F., and it is stated that an exposure of four or five minutes heats the bale so that it takes two hours for it to fall below 215° F. An escape in the upper part of the box is provided with a bath for the purpose of preventing the passage of any disease germs into the air.

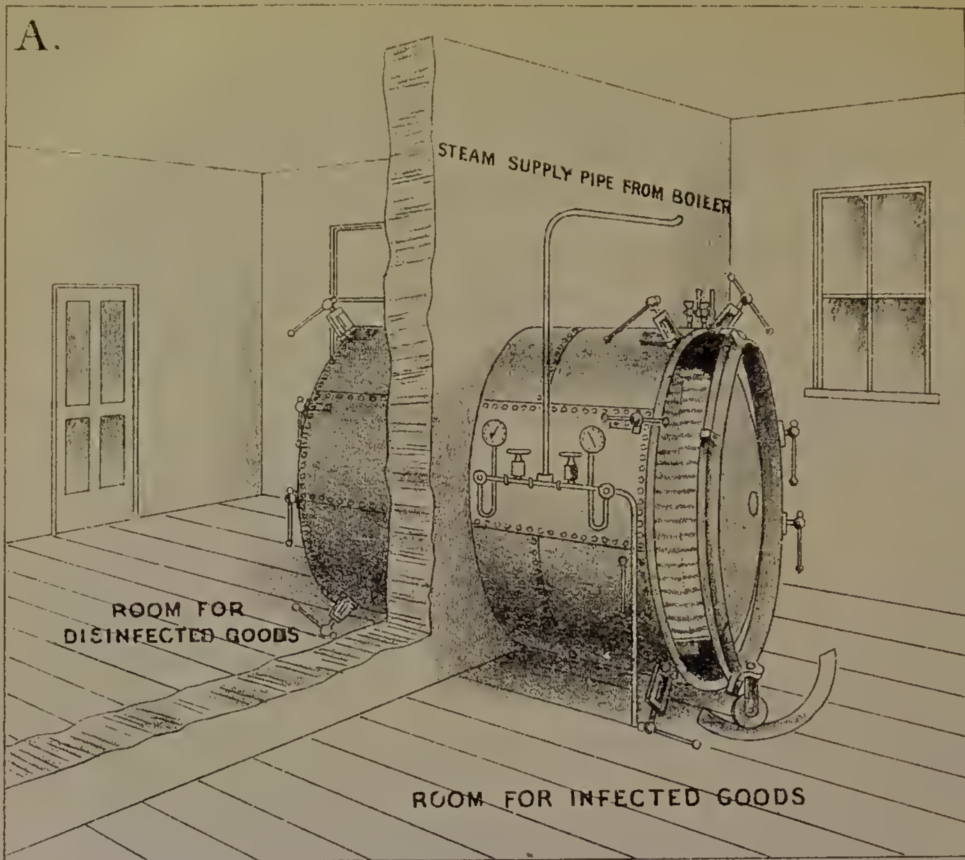
Dr. G. M. Sternberg, of the Johns Hopkins University, Baltimore, gives me the following account of an experiment with this apparatus :—

"In an experiment made in my presence, after two or three minutes during which the steam was turned on at a pressure of 80 lbs., the temperature of the interior of the bale after the screws were withdrawn was 250° F. I inserted pledgets of cotton infected with anthrax spores and other organisms into a bale at various points. It was then disinfected as above indicated, and I found by culture experiments that the vitality of the spores had been destroyed."

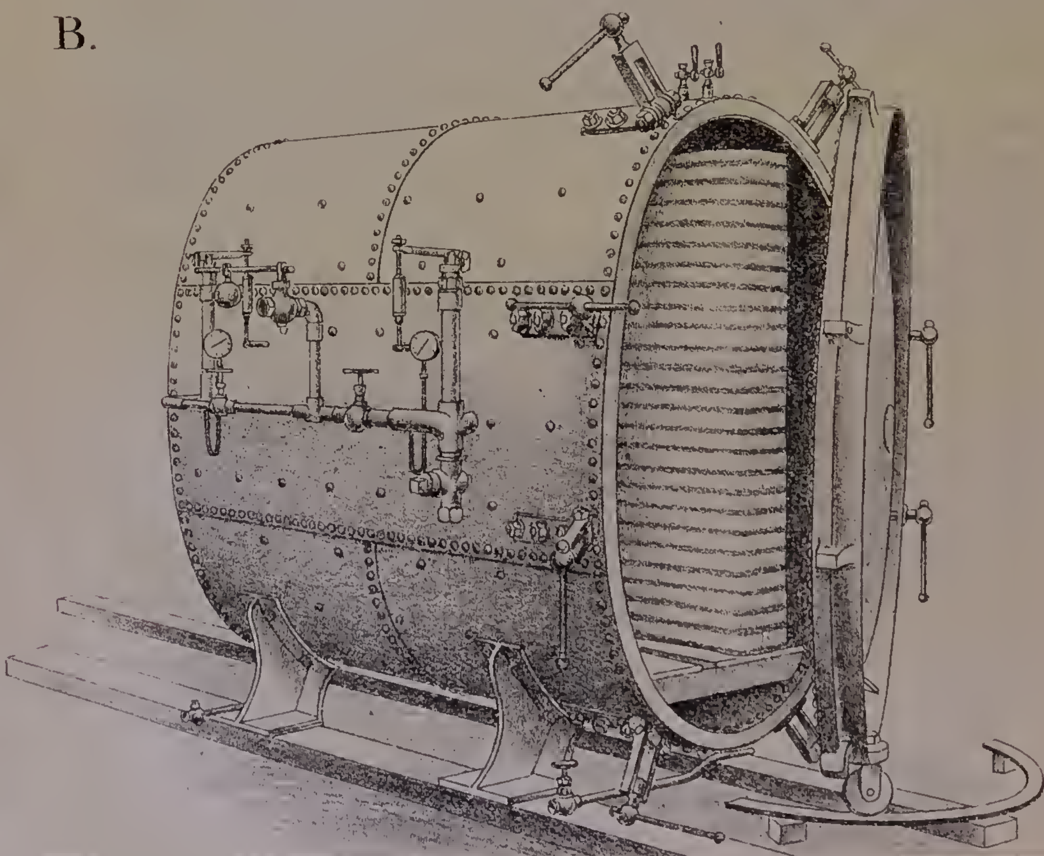
An apparatus for the disinfection by steam of walls of infected rooms is described and figured by Mr. Eassie, C.E., in the "Sanitary Record," February 15th, 1881, p. 285. It is the invention of Messrs. Weyer & Richardson, and is stated to be in use in France, but its use cannot be frequent, for M. Vallin in his very comprehensive work on disinfectants and disinfection published in 1883 makes no mention of it, nor have I been able to learn from Mr. Eassie of any place where it is in use. The apparatus consists of a portable five-horse power boiler for the generation of steam, under a pressure of 75–90 lbs. The steam, charged with disinfecting vapour, is conveyed through an india-rubber hose, ending in a copper spout furnished with a wooden handle, and with nozzles of different shapes, according to the shape of the surface to be operated on. Steam generated in the boiler, which is stationed outside the infected house, in the same manner as a fire-engine, is carried by

Of walls of houses.

A.


STEAM SUPPLY PIPE FROM BOILER
ROOM FOR DISINFECTED GOODS
ROOM FOR INFECTED GOODS

B.



the hose into the room to be disinfected, and is directed against the wall; the spout being held in contact with the surface and moved over it, so that every part of the surface is in turn subjected to the action of the steam. It is stated that the surface can be thus treated at the rate of two square yards per minute. The action of the steam destroys wall paper, whitewash, and distemper, but not oil paint, which indeed is said to be restored to its original brightness.

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6.—*Apparatus employing Steam confined under Pressure.*

WASHINGTON LYON'S PATENT STEAM DISINFECTOR.

Lyon's patent steam disinfector.

(Makers, Messrs. MANLOVE, ALLIOTT, & Co., Nottingham.)

This machine consists of a large and strong iron chamber with double walls of boiler plate, and provided with a tightly-fitting door at one or both ends. The chamber is usually made elliptical in section, the long diameter of the ellipse being vertical, for the more convenient reception of bulky articles, as mattresses, sofas, &c. In its original form it had a door hung on hinges at one end only, the back being steam jacketed like the circumference; this form was made to run on wheels for removal from place to place, if desired. Another form designed for a town disinfection station and intended to be placed in the partition wall dividing the building into two sides for infected and disinfected articles respectively, was cylindrical, and had a door at either end, the doors being balanced one against the other on a chain or levers, so that when one rose the other dropped into a pit for its reception. This arrangement necessitated the establishment of a direct communication between the two sides of the building through the machine every time that it was opened, and when the doors were suspended upon levers, holes in the partition wall were necessary in order to give the levers room to play. The objection has been obviated in the more recent machines by making the doors to open independently; the door turning on hinges, and its weight being borne by a castor running on a curved rail. (*See* figure.)

At my suggestion Messrs Manlove, Alliott, and Company have planned a portable form of the apparatus, containing furnace, boiler, and steam chamber in one piece, on two wheels. They inform me that it would weigh 30 cwt., and could be made for about 150*l.* No example, however, has yet been constructed.

The door shuts against an indiarubber collar, and is secured by screws with vice handles so as to form a steam-tight joint. In the earlier machines the door was secured by a large number of nuts and bolts fitting into notches in the rim of the door, and into corresponding notches in a flange surrounding the open end of the chamber; the opening and closing of the door was then a tedious business, but successive improvements have greatly increased the facility and celerity with which it can be effected, so that now the door can be opened by one man in a minute and a half.

By means of a steam-pipe steam from a boiler can be admitted into either the hollow casing or the interior of the chamber; another pipe serves to let off the steam when no longer required, and there is also a means of escape for condensed water which may accumulate in the casing. The casing and chamber are each provided with a safety valve and a pressure gauge, by which the pressure of steam, and by consequence the temperature, can at any moment be seen.*

---

* In the gauges now made, the degrees of temperature corresponding to the seve al pressures are marked on the dial.

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In using the apparatus steam is first turned on to fill the casing, thus heating the walls of the chamber. While this is going on the articles to be disinfected are placed inside the chamber, and the door is shut and tightly screwed up. The steam is then turned into the interior of the chamber until the gauge shows a pressure corresponding to the temperature which it is desired to reach. If the steam-cock leading to the chamber be soon shut off, the pressure in the chamber falls, owing to the steam becoming partly condensed in imparting its heat to the articles placed therein, but when these have become thoroughly heated, the pressure in the chamber remains nearly constant when the cock is closed, loss of heat by radiation being prevented by the steam-casing except on the side of the door. The constancy of the pressure in the chamber when communication with the boiler is cut off is thus in some measure an index of the extent to which the heat has penetrated the articles placed in it.

By loosely closing the door, and turning steam into the outer casing only, the effect of dry heat at atmospheric pressure can be obtained. On the other hand, by employing a higher pressure of steam on the outer casing than on the interior of the chamber, the steam in the latter can be superheated, *i.e.*, made to attain a higher temperature than that corresponding to its pressure. This is illustrated by the following experiment :—

Experiments on distribution of heat.

Five registering thermometers were hung up within the machine from hooks at the top, so as to be at the same level and at equal distances apart. The door was then closed, and steam applied at a 29 lb. pressure (=270°·5 F.) on the outer case, and at 16 lbs. pressure (=253° F.) on the interior. At the end of about 10 minutes the thermometers were found to read respectively, beginning with that nearest the door, 257°, 258°, 260°, 264°, and 265° F. This experiment also shows that the temperature in the chamber is not absolutely uniform.

In practice there is found to be a convenience in using a greater pressure on the casing than on the interior, as in this way a higher temperature may be attained without an inconvenient increase of pressure such as would make it difficult to keep the door tight. The superheating of the steam, too, making it what is called dry steam, prevents to a large extent the condensation of moisture in the articles to be disinfected.

It is found also that the penetration of heat into bulky objects is more readily brought about if the steam, instead of being maintained for the whole time at a constant pressure, be from time to time let off and re-applied, so as to displace the cold air remaining in the interstices of the material.

Some experiments in 1881 were made with a small copper model, but the greater part of those to be described were made in a machine measuring 13 feet by 6 feet by 4 feet.

To illustrate advantage of steam pressure.

In the earlier experiments with the model a registering thermometer was well wrapped up in a sheet of cotton wool, loosely tied, and was exposed for varying periods to steam at a pressure of 28 lbs. =273° F. After an exposure of half an hour the thermometer registered 270° F. After exposures of a quarter of an hour and of five minutes equally high temperatures were recorded, but after an exposure of three minutes the index stood only at 260° F., showing that the heat had not in that brief time thoroughly penetrated the cotton wool.

To ascertain how far the penetration of heat was aided by pressure, in another experiment, after the casing had been thoroughly heated by

steam at 30 lbs. pressure, two thermometers, one wrapped in cotton wool as before, the other bare, were introduced into the chamber, and the door loosely closed. A little steam was at first let into the chamber in order that the circumstances of the experiment might be similar to those of the former, except in respect of pressure, and the heat of the outer casing was maintained for half an hour. At the end of that time the exposed thermometer registered 250° F., the one wrapped in cotton wool only 217° F. The pressure thus appears to aid the penetration of the heat. On Disinfection by Heat; by Dr. Parsons.

The following experiments on a larger scale illustrate the same point:—

(A.) A bale of white rags, weighing 186 lbs., loosely packed, was placed in the machine, and steam at 15 lbs. pressure =251° F. admitted into both casing and interior. At the end of an hour a thermometer in the centre of the bale registered 212° F. The bale had gained 16 lbs. in weight, but next morning (16 hours later) the increase of weight was only 2 lbs. The temperature in the interior was then 91° F., that of the air being 70° F.

In this experiment the steam in the chamber was twice during the hour let off and re-applied.

Another experiment was attempted with the same bale and steam at 15 lbs., the pressure being maintained constant for an hour. On this occasion the thermometer in the interior of the bale was unfortunately broken, but it was manifest that the heat had penetrated.

(B.) The same bale of white rags now weighing 188 lbs., loosely packed, was placed in the machine, the door was closed, but the safety valve was fastened open, so that there could be no pressure on the interior of the chamber. Steam at 30 lbs. pressure =276° F. was let into the outer casing, but none was admitted into the interior. At the end of five hours a thermometer in a hole bored into the centre of the bale registered 192° F., while one hung up in the machine registered 272° F.

The following experiments show the advantage of intermitting the pressure when objects difficult of penetration have to be dealt with:— On advantage intermitting pressure.

I. (*a.*)—A tightly trodden bale of white rags was placed in the machine for two hours, with steam at 15 lbs. pressure on both the casing and interior, the steam being let off from the interior and re-applied every 20 minutes. At the end of two hours a thermometer in the centre of the bale registered 170° F.; a thermometer suspended in the machine showing 260°.

(*b.*) The experiment was repeated two days later with the same bale and under the same conditions, except that the pressure of steam was kept constant. At the end of two hours the thermometer in the bale registered 85° F., that suspended in the machine marked 255° F.

II. (*a.*)—Into a pillow 2 feet long, 1 foot broad, and 6 inches thick, weighing $6\frac{1}{2}$ lbs. (it containing the feathers out of two ordinary pillows of the same size), a thermometer was pushed, and it was hung up in the machine and exposed to steam at 15 lbs. pressure on both jacket and chamber for half an hour, the pressure during that time being once remitted. At the end of the time the thermometer registered 212°.

(*b.*) The experiment was repeated with the same pillow, but a steam pressure of 15 lbs was maintained for half an hour without intermission. At the end of that time the thermometer in the pillow registered 185° F.

The following experiments prove the power of the machine to cause penetration of heat into the interior of bulky and badly-conducting articles:—

On Disinfection by Heat: by Dr. Parsons.

On penetration of heat into bales of rags, &c.

Experiment.

A full-sized bale of press-packed cotton rags measuring 3 feet 6 inches by 3 feet by 2 feet 3 inches, and weighing 5 cwt., was placed in the machine and exposed for four hours to steam at 15 lbs. pressure relaxed every half hour, the pressure of steam in the jacket being maintained at 30 lbs. At the end of the four hours a thermometer in the bale registered 258° F.

Five minutes after opening the machine the temperature in the centre of the bale had fallen to 220° F., and 10 minutes later to 212° F. Next day it was 140° F., on the third day 100° F., and on the fourth day 85° F. It will be observed that on the removal of the pressure, the temperature rapidly fell to the boiling point of water (this was observed in other experiments), but that after this the loss of heat was comparatively slow, showing how difficult is the passage of heat through a hydraulic-pressed bale of rags. In the hand-packed bale the temperature fell as much in one day as in the press-packed bale it did in three days.

The bale in the above experiment was found on removal from the machine to have gained in weight 27 lbs., or 4·8 per cent.

As a doubt was raised whether the hole in which the thermometer had been placed was sufficiently plugged to prevent the steam finding its way to the thermometer,* the experiment was repeated under similar conditions, except that the hole, instead of as in the previous experiment being stuffed with rag, was firmly plugged with a conical wooden plug. After four hours exposure the thermometer in the bale registered 252° F., that hung up in the machine marking 273° F.

At the end of three hours, however, in another similar experiment with the same bale, the temperature had only reached 206° F., showing that four hours is the minimum length of exposure that will suffice under the conditions to attain a temperature that may be relied on for thorough disinfection.

Experiment.

A bale of woollen rags not press-packed, weighing 549 lbs. (nearly 5 cwt.), was placed in the machine for two hours, the pressure of steam being 15 lbs. in the chamber and 30 lbs. in the jacket. The pressure in the chamber was relaxed and re-applied every half hour. At the end of two hours the thermometer in the bale registered 255° F. The bale had increased in weight 25 lbs., or 4·4 per cent.

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* In these experiments the temperature of the interior of the bale was ascertained by placing a maximum-registering thermometer graduated on the stem and having a string attached to the upper end in a hole bored with an auger into the centre of the bale. The thermometer was inserted before the bale was exposed to the steam the hole being plugged. The satisfactory plugging of the hole was a problem of some difficulty. At first a long strip of rag was used, being pushed in bit by bit after the manner of a surgical tampon. It appeared possible, however, that the plug might be more permeable than the mass of the bale. To prevent the bulb of the thermometer coming in contact, on its withdrawal, with the heated layers next the surface, and thus indicating a higher temperature than that of the centre of the bale, it was in some experiments wrapped up in linen, but this was found to get caught, so that the thermometer was with difficulty withdrawn. Another difficulty in loosely packed bales was the falling about of the rags when heated; in this way two thermometers were snapped across by the weight of rags pressing on them. To prevent this, the thermometer was placed in a wooden tube having perforations opposite the bulb, the upper end being closed with a cork; this, however, was not found very satisfactory. Eventually the best and simplest plan was found to be a conical wooden plug firmly forced into the bore hole, which the plug securely closed, and on its removal left clear for the rapid withdrawal of the thermometer.

Thus the woollen rags were more easy of penetration than the press-packed cotton rags, the tightness of packing in the one case more than counter-balancing the inferior conductivity of the material in the other.

On Disinfection by Heat; by Dr. Parsons.

It might perhaps be thought that a loosely packed material would be less permeable to heat than a tightly packed one, in the same way as a flag-stone or a wooden board transmits heat more readily than an equivalent weight of sand or sawdust. The analogy, however, does not hold good between the conduction of heat through a solid substance, and its conveyance through the interstices of a material by currents of heated air or vapour.

On relative penetrability of tightly and loosely packed articles.

To illustrate this point the following experiment was made :—

Two pillows, each 2 feet long, 1 foot wide, and 6 inches thick, were taken ; one contained the ordinary quantity of feathers, about 3¼ lbs., the other a double quantity, about 6½ lbs. A thermometer was pushed into the centre of each, and they were hung up in the machine for half an hour, steam being applied at 15 lbs. pressure on both chamber and case, and once relaxed. At the end of half an hour the thermometer in the fuller pillow registered 212° F., in the less full pillow 239° F.

Experiment.

In a tightly trodden bag of feathers 3 feet high and 5 feet girth, weighing 54 lbs., a hole was bored and a thermometer placed. It was exposed for half an hour to steam at 15 lbs. pressure, intermitted once. At the end of the time the thermometer registered only 80° F. On account of the value of the feathers and their liability to injury by prolonged heat, it was not thought practicable to ascertain what length of time would be necessary to penetrate them when so tightly packed, but the same feathers taken out and placed in a mattress tick were penetrated in an hour by steam at 15 lbs. pressure, intermitted twice, the thermometer in the interior registering 240° F.

Experiment.

Ten horse-hair mattresses, each weighing about 20 lbs. were piled upon one another in the machine. In one of the centre ones a thermometer was inserted. Steam was applied for half an hour at 20 lbs. pressure in the chamber and 24 lbs. in the casing ; the pressure in the chamber being once intermitted. At the end of half an hour the thermometer in the mattress registered 242° F., and one hung up in the machine 260° F.

With mattresses.

Along with the bag of feathers lately mentioned a similar mattress was exposed for half an hour to steam at 15 lbs. pressure once intermitted. The thermometer in its interior registered 244° F.

Benham and Sons' Steam Disinfector.

(Makers, Benham and Sons, Wigmore Street, London, W.)

Benham's steam disinfector.

This machine acts on the same principle as Lyon's, from which it differs only in details of construction. As exhibited at the Health Exhibition, it consisted of a rectangular iron chest, resembling a fire-proof safe, the internal dimensions of which were 3 feet long, 1 foot 6 inches broad, and 3 feet 6 inches high. It is surrounded by a steam jacket, 1 inch thick, except on the side formed by the door and for a space 3 inches in width surrounding it. The chest itself is of cast iron, the outer wall of the jacket being $\frac{3}{16}$-inch boiler-plate. Steam from a boiler can be admitted both into the casing and into the

On Disinfection by Heat; by Dr. Parsons.

interior of the chamber. There is a cock on the main steam pipe and one on each branch, and there is a single pressure-gauge and a safety-valve on that portion of the pipe between the cock on the main pipe and those on the branches. There is a pipe communicating with the chamber and closed by a valve, to serve as an outlet for air or waste steam, and there are also outlets for condensed water at the bottom. There is at the top a funnel closed by a pair of cocks with a bulb between them, by which a volatile liquid disinfectant can be allowed to drop in to the chamber; the utility of this latter arrangement is not obvious. The door is formed of a plate of cast iron strengthened by ribs, and opening on hinges. The face against which it shuts is furnished with an indiarubber collar let into a groove. The door is secured by a single large screw in the centre, working into a female screw in a strong iron bar which lies across the mouth of the chamber, resting in a groove on either side, so that it can be removed to allow articles to be placed in the chamber. This form of fastening allows the door to be opened or closed with great facility and expedition, but is not adapted to sustain a high pressure. In an experiment with a machine at Messrs. Benham's works steam escaped in large volumes at the corners of the door when the pressure reached 9 lbs.

The following experiments were made with the machine just mentioned :—

Experiments.

Experiment 1.

The machine being cold, the temperature of the air being 65° F., a pair of registering thermometers arranged as wet and dry bulb were suspended in the centre of the chamber, and three other registering thermometers were placed in different parts of the chamber ; the door was closed and the steam turned on. In 25 minutes the pressure indicated by the gauge had reached $10\frac{1}{4}$ lbs., and the chamber was then opened. The thermometers were found to read as follows :—

On distribution of heat in chamber.

Centre of chamber	Dry bulb	237° F.
	Wet bulb	234° ,,
4 inches from back wall		$238\frac{1}{2}$° ,,
4 inches from door		$237\frac{1}{2}$° ,,
On rack at bottom		239° ,,

The water in the vessel supplying the wet-bulb thermometer had most of it evaporated.

These results show that the temperature within the chamber is very uniform, and that the steam in the inner chamber is in a state almost of saturation.

In Lyon's machine a difference of 8° instead of only 2° was found in the temperature in different parts of the chamber, and the wet and dry-bulb thermometers showed a difference of 17°. The difference in the two cases is due to the steam in Lyon's machine being used at a higher pressure in the casing than in the chamber, so that that in the latter is to some extent superheated, while in Benham's the same pressure is used upon both casing and chamber.

Experiment 2.

The following articles were placed in the chamber :—

On penetration of heat into pillows, &c.

A. A flock pillow, weighing 3 lbs. $4\frac{1}{4}$ ozs. with a thermometer inside.

B. A piece of flannel 9 feet 3 inches long, weighing 1 lb. $7\frac{1}{2}$ ozs. : this was rolled up with a thermometer inside.

C. A cloth coat weighing 2 lbs. $6\frac{1}{2}$ ozs. rolled up into a bundle with a thermometer in the middle.

The machine having been closed and the steam turned on, in four minutes the gauge indicated 10 lbs. and the safety-valve, which had been set at 10 lbs., blew off. Two minutes later the packing of the door gave way and the chamber was then opened. A thermometer suspended inside registered 240° F.

On Disinfection by Heat; by Dr. Parsons.

A. The pillow weighed 3 lbs. 11 ozs.; it had thus gained in weight $6\frac{3}{4}$ ozs., or 12·9 per cent., in other words, a third of a pint of water had condensed in it. The thermometer in the centre registered $171\frac{1}{2}$° F.

B. The flannel had gained in weight 5 ozs. or 21 per cent.; it had shrunk in length $2\frac{1}{2}$ inches or 2·2 per cent. The thermometer inside it registered 229° F.

C. The coat had gained in weight 13 ozs. of which $6\frac{1}{2}$ ozs. were lost on exposing to the air for $1\frac{1}{2}$ hours: the thermometer inside it registered 238° F.

Experiment 3.

The following articles were placed inside the chamber, together with a registering thermometer:—

A. A flock pillow, weighing 3 lbs. 8 ozs., with a thermometer inside it.

B. The same piece of flannel as before now weighing (without thermometer) 1 lb. 6 ozs. This was hung loose over a bar.

C. The same coat as before, now weighing 2 lbs. $13\frac{1}{2}$ ozs.

The door being fastened and the steam let into the chamber, in eight minutes the pressure had reached 10 lbs., at which it was kept for ten minutes; the steam was then shut off from the chamber and the exhaust pipe opened, but steam at 10 lbs. was kept in the casing for five minutes longer. At the end of that time the bare thermometer registered 240°.

A. The pillow weighed 4 lbs.; the thermometer inside it registered 234°.

B. The flannel had gained in weight $3\frac{1}{2}$ ozs.; there was no further shrinkage.

C. The coat weighed 3 lbs. 7 ozs.; it had gained in weight $9\frac{1}{2}$ ozs. instead of 13 ozs., as in the last experiment.

The above experiment shows—

1. That ten minutes exposure to steam at 10 lbs. pressure is sufficient to secure the penetration of a heat sufficient for disinfecting an ordinary pillow.

2. That little drying effect was obtained by the use of the hot steam casing in the absence of a current of air through the apparatus.

Experiment 4.

When wet.

The flock pillow was placed under a tap and saturated with cold water; it then weighed 8 lbs. 6 ozs. A thermometer was then placed inside it, and it was inserted in the chamber and steam applied at 10 lbs. pressure for 20 minutes. At the end of that time the thermometer in the interior registered 216°.

This experiment gives a strong illustration of the power of steam under pressure to penetrate an article in a moist state. No such penetration by dry heat, on the other hand, could have been obtained until all the moisture had been evaporated.

Experiment 5.

A feather pillow, weighing 3 lbs. 10 ozs., was exposed to steam at 10 lbs. pressure for 10 minutes. At the end of that time a thermometer in the centre registered 234°; the pillow weighed 3 lbs. 14 ozs.

On Disinfection by Heat; by Dr. Parsons.

Bradford's steam disinfector.

There would thus appear to be little difference between the conducting power of flock and of feathers, at any rate when steam is employed.

Bradford's Steam Disinfector.

(Makers, Thos. Bradford & Co., Salford.)

This apparatus, which was seen at the maker's works, is a horizontal cylinder of boiler plate, 7 feet long and 4 feet in diameter, supplied with steam from a boiler. It is covered with a non-conducting composition. It has not a complete steam jacket, but there is a square steam chamber applied to the bottom, into which steam can be let by a branch pipe in order to warm the cylinder: this chamber is furnished with a "steam trap" to run off condensed water. The cylinder is provided with exhaust pipe, safety valve, and pressure gauge. It has a door at either end: the doors are hung from wheels running on bars overhead. Each door is fastened by 16 hinged screws fitting into notches in the lid. The closing of each door takes one man five minutes, the opening takes rather less.

The following are the instructions for its use:—

"The cylinder to be warmed by turning on steam into the heating chamber which may be done till the pressure rises to 20 lbs. The steam to be maintained on the heating chamber during the whole time the apparatus is being used. If there be frequent use of the apparatus, time is saved by keeping it constantly warm. Should No. 2 door not be screwed up, it should be attended to before infected articles are brought into No. 1 room, so as to isolate No. 2 room.

"The warming of the cylinder can be assisted by closing No. 1 door.

"After the cylinder has been warmed, articles to be disinfected are introduced through No. 1 door, which is then to be screwed up. The steam is then to be admitted into the cylinder and maintained there at a steady pressure of 15 lbs., which gives a heat of 250°.

"The length of time needful for the operation of disinfecting varies according to different medical authorities. Articles placed loosely in the cylinder are thoroughly penetrated by the heat and vapour in 10–15 minutes, but for beds, mattresses, &c., it will not be safe to allow less than an hour.

"After the period allowed for disinfection has elapsed, the steam is to be shut off the cylinder, and No. 2 door opened a little to assist in drying the articles."

Experiment 1.

The steam in the boiler standing at 20 lbs., and steam being in the heating chamber, six thermometers were placed in the cylinder. Another thermometer was inserted into a flock pillow, weighing $2\frac{3}{4}$ lbs., which was also placed in the cylinder. The doors were closed and steam let into the cylinder at 3.4; at 3.9 the gauge indicated 13 lbs., and at 3.14 16 lbs. The steam was then let off and the door opened.

The thermometers registered as below:—

1. Mid-height, near end	210°
2. Ditto mid-length	211°
3. Ditto far end	205°
4. Mid-length, bottom (above heating chamber)	224°
5. Ditto near top	215°
6. On pillow „	205°
7. In pillow	182°

The pillow was very wet, weighing 4 lbs., an increase of 44 per cent. There was much condensed water in the cylinder, some of which may have reached the pillow.

Experiment 2.

The thermometers and pillow (cold) having been placed as before: steam (which stood at 40 lbs. in the boiler) was turned into the cylinder at 3.47. At 3.55 the gauge on the cylinder stood at 22 lbs.; at 4.7, 26 lbs.; at 4.17, 25 lbs.: the steam was then let off.

The thermometers read :—

1. Mid-height, near end	- - -	253°
2. Ditto mid-length	- - -	251°
3. Ditto far end	- - -	251°
4. Mid-length, bottom	- - -	250°
5. Ditto near top	- - -	252°
6. In pillow	- - - - -	251°

The performance of this apparatus though more rapid than that of any of the dry heat ones is less satisfactory than that of Lyon's, on account of the much greater amount of condensation which takes place, owing doubtless to the incompleteness of the steam jacket. Nor was the temperature attained in the interior so high as according to the pressure it should have been.*

The only advantage it seems to possess over Lyon's is that the mode of construction would probably render it cheaper.

VII.—*Summary*.

1. With the exception of spore-bearing cultivations of the bacillus of anthrax, all the infective materials experimented on were destroyed by an hour's exposure to dry heat of 220° F., or five minutes' exposure to steam at 212° F. Spores of bacillus anthrax required for destruction four hours' exposure to dry heat of 220° F., or one hour's exposure to dry heat of 245° F., but were destroyed by five minutes' exposure to a heat of 212° F. in steam or boiling water.

It may be assumed that the contagia of the ordinary infectious diseases of mankind are not likely to withstand an exposure of an hour to dry heat of 220° F., or one of five minutes to boiling water or steam of 212° F.

2. Dry heat penetrates very slowly into bulky and badly-conducting articles, as of bedding and clothing; the time commonly allowed for the disinfection of such articles being insufficient to allow an adequate degree of heat to penetrate into the interior.

Steam penetrates far more rapidly than dry heat, and its penetration may be aided by employing it under pressure, the pressure being relaxed from time to time, so as to displace the cold air in the interstices of the material.

In hot air the penetration of heat is aided by the admixture of steam, so as to moisten the air, but hot moist air did not appear to have a greater destructive effect upon spores of anthrax bacilli than dry heat.

3. Scorching begins to occur at different temperatures with different materials, white wool being soonest affected. It is especially apt to occur where the heat is in the radiant form. To avoid risk of scorching the heat should not be allowed much to exceed 250° F., and even this temperature is too high for white woollen articles.

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* Probably this was partly due to the air in the interior not having been let out, so that the pressure was that of steam plus air, while the temperature was lowered by admixture with the cold air.

On Disinfection by Heat; by Dr. Parsons.

4. By a heat of 212° and upwards, whether dry or moist, many kinds of stains are fixed in fabrics so that they will not wash out. This is a serious obstacle in the way of the employment of heat for the disinfection previous to washing of linen, &c., soiled by the discharges of the sick.

5. Steam disinfection is inapplicable in the case of leather, or of articles which will not bear wetting. It causes a certain amount of shrinkage in textile materials, about as much as an ordinary washing. The wetting effect of the steam may be diminished by surrounding the chamber with a jacket containing steam at a higher pressure, so as to superheat the steam in the chamber.

6. For articles that will stand it, washing in boiling water (with due precautions against re-infection) may be relied on as an efficient means of disinfection. It is necessary, however, that before boiling the grosser dirt should be removed by a preliminary soaking in cold water. This should be done before the linen leaves the infected place.

7. The objects for which disinfection by dry heat or steam is especially applicable are such as will not bear boiling in water, *e.g.*, bedding, blankets, carpets, and cloth clothes generally.

8. The most important requisites of a good apparatus for disinfection by heat are (*a*) that the temperature in the interior shall be uniformly distributed; (*b*) that it shall be capable of being maintained constant for the time during which the operation extends; and (*c*) that there shall be some trustworthy indication to the actual temperature of the interior at any given moment. Unless these conditions be fulfilled, there is risk, on the one hand, that articles exposed to heat may be scorched, or on the other hand, that through anxiety to avoid such an accident the opposite error may be incurred, and that the articles may not be sufficiently heated to ensure their disinfection.

9. In dry-heat chambers the requirement (*a*) is often very far from being fulfilled, the temperature in different parts of the chamber varying sometimes by as much as 100°. This is especially the case in apparatus heated by the direct application of heat to the floor or sides of the chamber. The distribution of temperature is more uniform in proportion as the source of heat is removed from the chamber, so that the latter is heated by currents of hot air rather than by radiation.

10. In chambers heated by gas, when once the required temperature has been attained, but little attention is necessary to maintain it uniform, and in the best-made apparatus this is automatically performed by a thermo-regulator. On the other hand, in apparatus heated by coal or coke the temperature continually tends to vary, and can only be maintained uniform by constant attention on the part of the stoker.

11. In very few hot-air chambers did the thermometer with which the apparatus was provided afford a trustworthy indication of the temperature of the interior; in some instances there was an error of as much as 100° F. This is due to the thermometer, for reasons of safety and accessibility, being placed in the coolest part of the chamber, and to the bulb being enclosed for protection in a metal tube which screens it from the full access of heat. The difficulty may be overcome by using, instead of a thermometer, a pyrometer actuated by a metal rod extending across the interior of the chamber.

12. In steam apparatus the three requirements above mentioned are all satisfactorily met, and for this reason, as well as on account of the greater rapidity and certainty of action of steam, steam chambers are, in my opinion, greatly preferable to those in which dry heat is employed.

13. Without wishing to give the preference to one maker over another, I may mention that of the apparatus heated by coal, Bradford's newer machine; of those heated by gas, the Nottingham self-regulating

disinfecting apparatus; and of those employing steam, Lyon's patent steam disinfector, in my experiments gave the best results of any in their respective classes. On Disinfection by Heat; by Dr. Parsons.

14. It is important that the arrangement of the apparatus, the method of working, and the mode of conveyance to and fro should be such as to obviate risk of articles which have been submitted to disinfection coming into contact with others which are infected.

In concluding this report, I have to express my obligations, among others, to the authorities of the International Health Exhibition, of Thomas's Hospital, the London Fever Hospital, the Herbert Hospital at Woolwich, and of the Hampshire Nurses Institute, to the medical and other officers of the Limehouse, Portsmouth, Aston, and Leamington sanitary authorities, and of several workhouses, and to the respective makers for permission to experiment with their apparatus, and for other assistance during this investigation.

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